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XYLENES

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ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS MANUALS

Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals provide detailed information on chemical substances. This information is intended to assist the reader in designing countermeasures for spills and to assess their impact on the environment. The manual has been reviewed by the Technical Services Branch, Environmental Protection Service, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

EnviroTIPS manuals are available from

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XYLENES

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS

Technical Services Branch
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FOREWORD

The Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals were initiated in 1981 to provide comprehensive information on chemicals that are spilled frequently in Canada. The manuals are intended to be used by spill specialists for designing countermeasures for spills and to assess their effects on the environment. The major focus of EnviroTIPS manuals is environmental. The manuals are not intended to be used by first-response personnel because of the length and technical content; a number of manuals intended for first-response use are available. The information presented in this manual was largely obtained from literature review. Efforts were made, both in compilation and in review, to ensure that the information is as correct as possible. Publication of these data does not signify that they are recommended by the Government of Canada, nor by any other group.

ACKNOWLEDGEMENTS

The final version of this manual was prepared by the staff of the Environmental Protection Service who wrote extensive revisions to the text, drafted illustrations and incorporated all comments and additions.

The level of detail present was made possible by the many individuals, organizations and associations who provided technical data and comments throughout the compilation and subsequent review. The Canadian Chemical Producers' Association is especially acknowledged for its review of and input to this manual. The draft of this manual was prepared under contract to Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation, and Waterloo Engineering Limited.

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1 SUMMARY

XYLENES ($C_6H_4(CH_3)_2$)

Colourless, watery liquid with a sweet odour

SYNONYMS

Dimethylbenzene, Xylol, Mixed Aromatic Hydrocarbons; o-Xylene: 1,2-Dimethylbenzene, *o*-Xylol; *m*-Xylene: 1,3-Dimethylbenzene, *m*-Xylol; p-Xylene: 1,4-Dimethylbenzene, *p*-Xylol

IDENTIFICATION NUMBERS

UN No. 1307; CAS No. 108-38-3 (m), 95-47-6 (o), 106-42-3 (p); OHM-TADS No. 7216951 (p), 7216952 (o), 7216953 (m); STCC No. 4909350 or 4909351

GRADES & PURITIES

Mixed Xylenes (solvent grade): >84 percent *o*-, *m*- and *p*-xylenes, mixed Ortho-depleted: 90 percent *o*- and *p*-xylenes

IMMEDIATE CONCERNS

Fire: Flammable. Flashback may occur along vapour trail. Vapour forms explosive mixtures with air

Human Health: Moderately toxic by inhalation

Environmental: Harmful to aquatic life at low concentrations

PHYSICAL PROPERTY DATA

	o-xylene	*m*-xylene	p-xylene
State (15°C, 1 atm):	liquid	liquid	liquid
Boiling Point:	144.4°C	139.1°C	138.35°C
Melting Point:	-25.18°C	-47.87°C	13.26°C
Flammability:	flammable	flammable	flammable
Flash Point:	32°C	27°C	27°C
Vapour Pressure:	1.3 kPa (32°C)	1.3 kPa (28°C)	1.3 kPa (27°C)
Density (25°C):	0.8802 g/mL	0.8642 g/mL	0.8610 g/mL
Solubility (in water): (22°C)	0.0228 g/100 mL	0.0187 g/100 mL	0.0191 g/100 mL
Behaviour (in water):	floats; no reaction		
Behaviour (in air):	vapour is heavier than air; forms explosive mixtures with air		
Odour Threshold:	0.3 to 5 ppm		

ENVIRONMENTAL CONCERNS

Xylenes are toxic to aquatic life at concentrations greater to than 2 mg/L. The material is hazardous to waterfowl and animals. Xylenes biodegrade slowly.

HUMAN HEALTH

TLV: 100 ppm (435 mg/m^3)
IDLH: 10 000 ppm

Exposure Effects

Inhalation: Causes headache, drowsiness, impairment, nausea, nose and throat irritation, and difficult breathing. At high concentrations, irritation of mucous membranes, central nervous system depression, and death may result

Contact: Contact with skin will cause irritation, dryness, erythema and dermatitis. Eye contact will cause irritation and possible reversible corneal injury

IMMEDIATE ACTION

Spill Control

Restrict access to spill site. Issue warning: "FLAMMABLE". Call fire department and notify manufacturer. Eliminate sources of ignition including traffic and equipment. Stop the flow and contain spill, if safe to do so. Avoid contact with liquid and inhalation of vapour; stay upwind of release. Keep contaminated water from entering sewers or watercourses.

Fire Control

Do not extinguish fire unless release can be stopped. Use foam, dry chemical, carbon dioxide, water spray or fog to extinguish. Cool fire-exposed containers with water. Stay clear of tank ends. Containers may explode in fires.

COUNTERMEASURES

Emergency Control Procedures in/on

Soil: Construct barriers to contain spill or divert to impermeable holding area. Remove material with pumps or vacuum equipment. Absorb residual liquid with natural or synthetic sorbents; shovel into covered containers

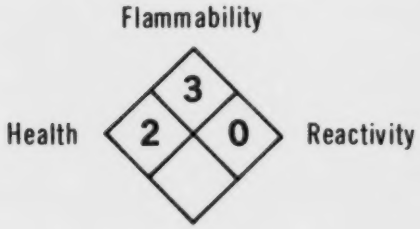
Water: Contain with booms, weirs or natural barriers. Use oil skimming equipment or suction hoses to remove slick, followed by the application of sorbents to remove final traces

Air: Use water spray to disperse vapour. Control runoff for later treatment and/or disposal

NAS HAZARD RATING

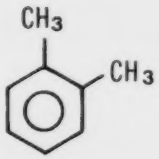
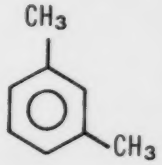
Category	Rating
Fire	3
Health	
Vapour Irritant	1
Liquid or Solid Irritant	1
Poison	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self-reaction	0

NFPA
HAZARD
CLASSIFICATION



2 PHYSICAL AND CHEMICAL DATA

Physical State Properties

	o- (ortho)	*m*- (meta)	*p*- (para)
Structural Drawing			
Appearance	Colourless liquids (Verschueren 1984)		
Usual shipping state(s)	Liquid	Liquid	Liquid
Physical state (15°C, 1 atm):	Liquid	Liquid	Liquid
Melting point	-25.18°C (CRC 1980)	-47.87°C (CRC 1980)	13.26°C (CRC 1980)
Boiling point	144.4°C (CRC 1980)	139.1°C (CRC 1980)	138.35°C (CRC 1980)
Vapour pressure	1.3 kPa (32°C) (CRC 1980)	1.3 kPa (28°C) (CRC 1980)	1.3 kPa (27°C) (CRC 1980)

Densities

Density (g/mL) (25°C)	0.8802 (Kirk-Othmer 1984)	0.8642 (Kirk-Othmer 1984)	0.8610 (Kirk-Othmer 1984)
Specific gravity, liquid (water = 1) (20°/4°C)	0.8802 (CRC 1980)	0.8642 (CRC 1980)	0.8611 (CRC 1980)
Specific gravity, vapour (air = 1)	3.7 (Verschueren 1984)	3.66 (Verschueren 1984)	3.7 (Verschueren) 1984)

Fire Properties

Flammability	Flammable liquids (NFPA 1978)		
Flash point	32°C (NFPA 1978)	27°C (NFPA 1978)	27°C (NFPA 1978)
Autoignition temperature	464°C (NFPA 1978)	528°C (NFPA 1978)	529°C (NFPA 1978)
Burning rate	5.8 mm/min (CHRIS 1978)	5.8 mm/min (CHRIS 1978)	5.8 mm/min (CHRIS 1978)
Upper flammability limit (v/v)	6.0 percent (NFPA 1978)	7.0 percent (NFPA 1978)	7.0 percent (NFPA 1978)

	o- (ortho)	m- (meta)	p- (para)
Lower flammability limit (v/v)	1.0 percent (NFPA 1978)	1.1 percent (NFPA 1978)	1.1 percent (NFPA 1978)
Heat of combustion (20°C)	4568 kJ/mole (CRC 1980)	4554 kJ/mole (CRC 1980)	4557 kJ/mole (CRC 1980)
Combustion products	Carbon dioxide and water (CRC 1980)		
Flashback potential	Vapour may travel considerable distance to a source of ignition and flash back (NFPA 1978)		
Explosiveness	Vapours form explosive mixtures with air (NFPA 1978)		
Electrical ignition hazard	May be ignited by static discharge		
Other Properties			
Molecular weight of pure substance	106.167 (Kirk-Othmer 1984)	106.167 (Kirk-Othmer 1984)	106.167 (Kirk-Othmer 1984)
Constituent components of typical commercial grades	95 percent mixture of xylenes containing predominantly meta and para isomers (CCD 1977)		
Refractive index (20°C)	1.5055 (CRC 1980)	1.4972 (CRC 1980)	1.4958 (CRC 1980)
Viscosity (20°C)	0.809 mPa•s (Ullmann 1983)	0.617 mPa•s (Ullmann 1983)	0.644 mPa•s (Ullmann 1983)
Liquid surface tension (20°C)	32.5 mN/m (Kirk-Othmer 1984)	31.23 mN/m (Kirk-Othmer 1984)	28.27 mN/m (Kirk-Othmer 1984)
Latent heat of fusion (at melting point)	13.6 kJ/mole (CRC 1980)	11.6 kJ/mole (CRC 1980)	17.1 kJ/mole (Kirk-Othmer 1984)
Latent heat of sublimation (25°C)	43.4 kJ/mole (Lange's Handbook 1979)	42.7 kJ/mole (Lange's Handbook 1979)	42.4 kJ/mole (Lange's Handbook 1979)
Latent heat of vaporization (25°C)	43.4 kJ/mole (Kirk-Othmer 1984)	42.0 kJ/mole (Kirk-Othmer 1984)	42.0 kJ/mole (Kirk-Othmer 1984)
Heat of formation (25°C)	-25.5 kJ/mole (Sussex 1977)	-25.4 kJ/mole (Sussex 1977)	-24.4 kJ/mole (Sussex 1977)
Entropy of formation	246.5 J/mole (Kirk-Othmer 1984)	252.2 J/mole (Kirk-Othmer 1984)	274.4 J/mole (Kirk-Othmer 1984)
Ionization potential	8.56 eV (Rosenstock 1977)	8.56 eV (Rosenstock 1977)	8.44 eV (Rosenstock 1977)
Heat capacity			
constant pressure (C_p) (J/(mole•°C)) (25°C)	181.66 (Kirk-Othmer 1984)	183.44 (Kirk-Othmer 1984)	181.66 (Kirk-Othmer 1984)

	o- (ortho)	m- (meta)	p- (para)
constant volume (C_v) (J/(mole•°C))	169 (30°C) (Perry 1973; CHRIS 1978)	158 (0°C) (Perry 1973; CHRIS 1978)	170 (25°C) (Perry 1973; CHRIS 1978)
Critical pressure	3730 kPa (Kirk-Othmer 1984)	3535 kPa (Kirk-Othmer 1984)	3511 kPa (Kirk-Othmer 1984)
Critical temperature	357.15°C (Kirk-Othmer 1984)	343.90°C (Kirk-Othmer 1984)	343.05°C (Kirk-Othmer 1984)
Coefficient of expansion (20°C)	0.960 x 10^{-3}/°C (Hancock 1982)	0.993 x 10^{-3}/°C (Hancock 1982)	1.002 x 10^{-3}/°C (Hancock 1982)
Thermal conductivity (0°C)	0.15 W/(m•K) (PPH 1984)	0.138 W/(m•K) (PPH 1984)	0.142 W/(m•K) (PPH 1984)
Dielectric constant (25°C)	2.568 (Kirk-Othmer 1984)	2.367 (Kirk-Othmer 1984)	2.27 (Kirk-Othmer 1984)
Dipole moment (C•m) (=D÷3.336x10^{-30})	0.51 (Kirk-Othmer 1984)	0.30 (Kirk-Othmer 1984)	0 (Kirk-Othmer 1984)
Evaporation rate	-	0.40 g/(m^2•s) (20°C, wind=4.5 m/s) (this work)	-
Saturation concentration (20°C)	29 g/m^3 (Verschueren 1984)	35 g/m^3 (Verschueren 1984)	38 g/m^3 (Verschueren 1984)
Henry's Law Constant			
- distilled water	0.219	0.314	0.314
- seawater	0.289 (NRC 1981)	0.433 (NRC 1981)	0.442 (NRC 1981)
Log_{10} octanol/water partition coefficient	2.77 (Chiou and Schmedding 1982)	3.20	3.15
Solubility			
In water			
- (22°C)	0.0228 g/100 mL (Miller 1976)	0.0187 g/100 mL (Miller 1976)	0.0191 g/100 mL (Miller 1976)
- in seawater	0.01296 g/100 mL (NRC 1981)	0.0106 g/100 mL (NRC 1981)	0.01109 g/100 mL (NRC 1981)
In other common materials	Soluble in ethanol, diethyl ether, acetone and benzene (CRC 1980)		

	o- (ortho)		m- (meta)		p- (para)	
Azeotropes (constant boiling-point mixtures)						
	%	b.p. (°C)	%	b.p. (°C)	%	b.p.(°C)
Acetic Acid	22	116.2	27.5	115.35	29	115.0
Butyl Alcohol	23	117.1	27	115.0	29	116.2
Glycol	84	140.0	85	135.8	85	135.2
Propionic Acid	57	135.4 (Hancock 1982)	64.5	132.65 (Hancock 1982)	66	132.5 (Hancock 1982)
Water	-	-	40	94.5	-	-
n-Hexanol	-	-	-	-	5	64.0
Ethylene Glycol	7	135.7	-	-	-	-
Methanol	All at 13-18%, b.p. = 138-143°C (Ullmann 1975)					

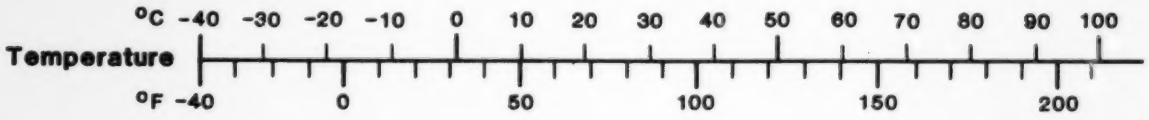
Vapour Weight to Volume Conversion Factor

1 ppm = 4.406 mg/m^3 (20°C) (Verschueren 1984)

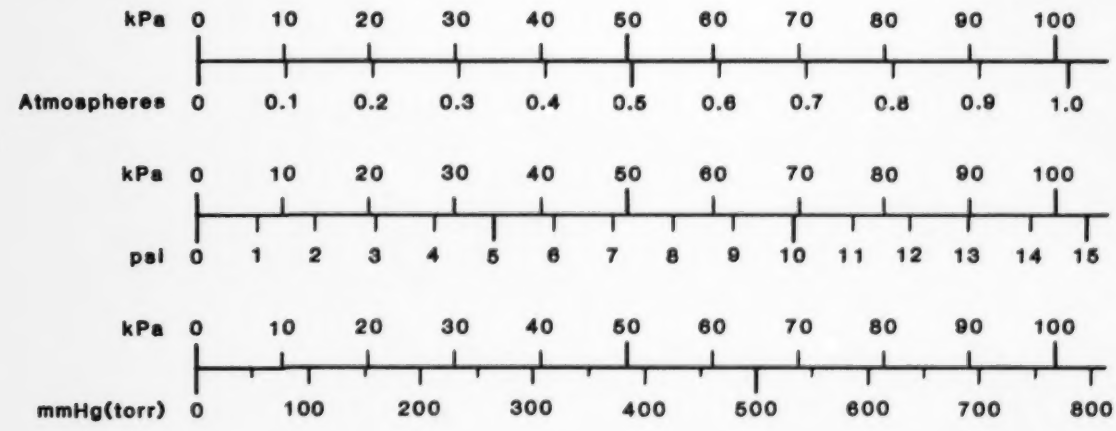
TABLE 1

XYLENES

CONVERSION NOMOGRAMS



Pressure 1 kPa = 1,000 Pa



Viscosity

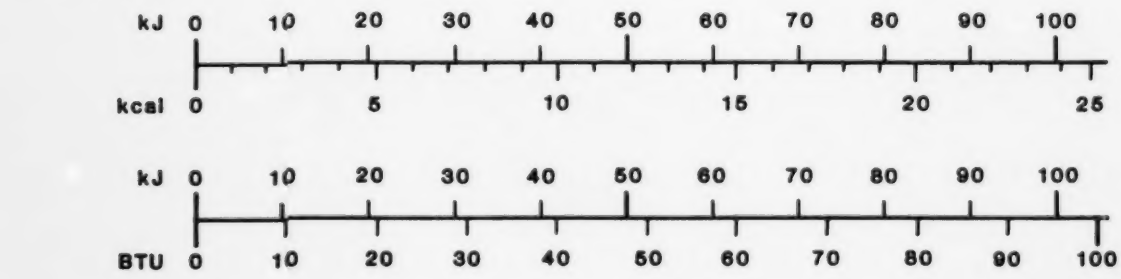
Dynamic 1 Pa·s ≙ 1 000 centipoise (cP)

Kinematic 1 m^2/s = 1 000 000 centistokes (cSt)

Concentration (in water)

1 ppm ≅ 1 mg/L

Energy (heat) 1 kJ = 1 000 J



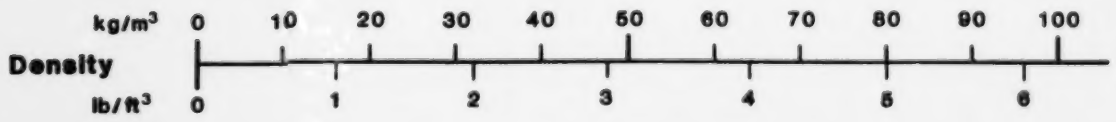


FIGURE 1

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VAPOUR PRESSURE vs TEMPERATURE

Reference: Chem. Eng. 1975

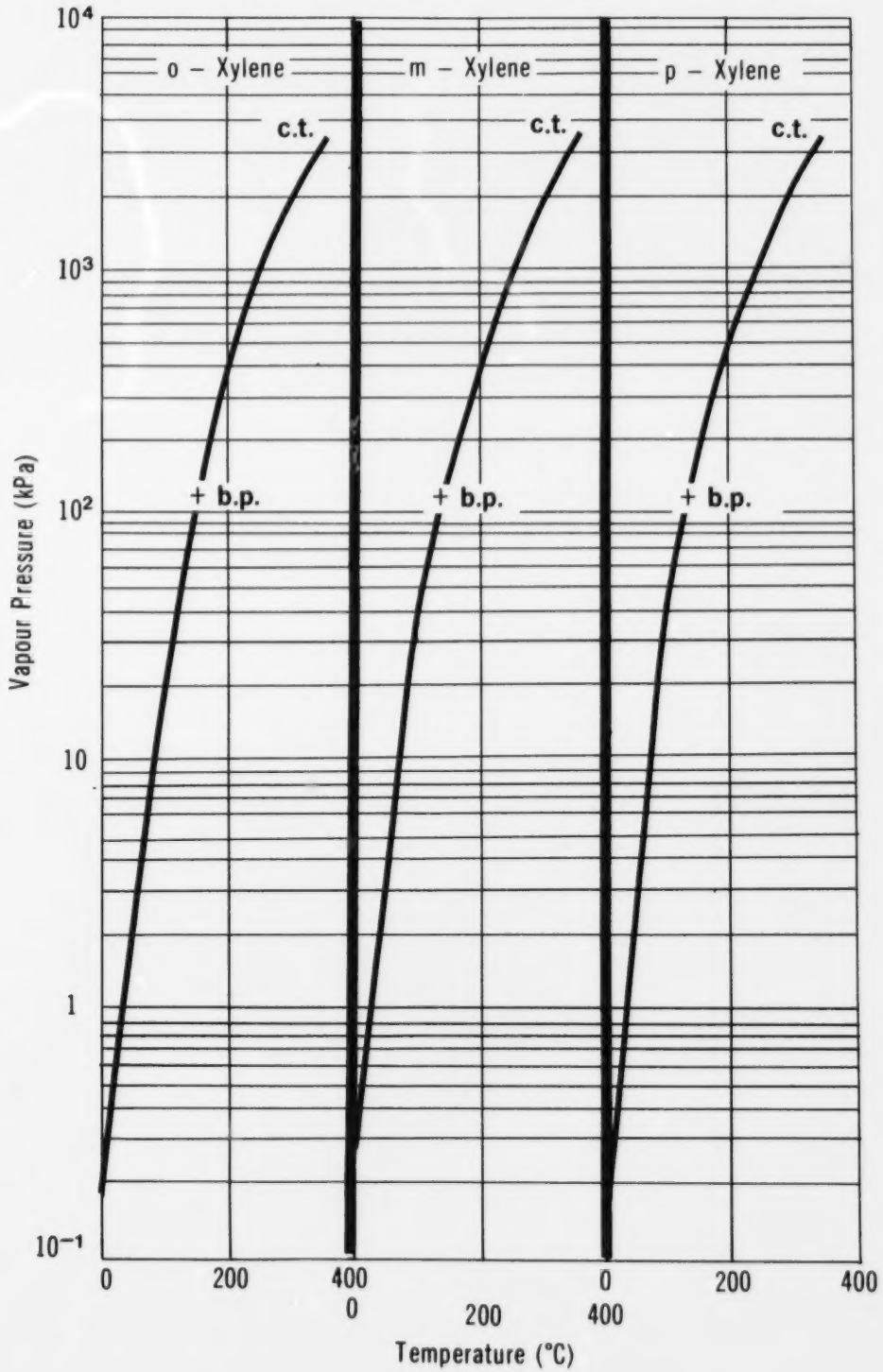


FIGURE 2

XYLENES

LIQUID DENSITY vs TEMPERATURE

Reference: Chem. Eng. 1975

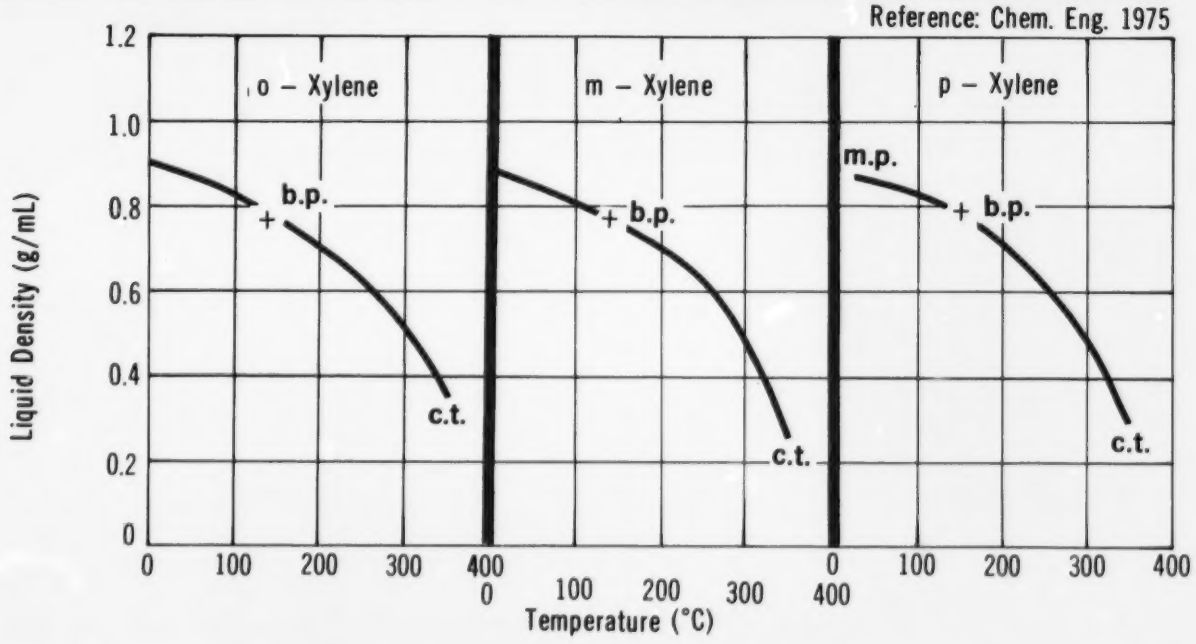


FIGURE 3

XYLENES

LIQUID SURFACE TENSION

Reference: Chem. Eng. 1975

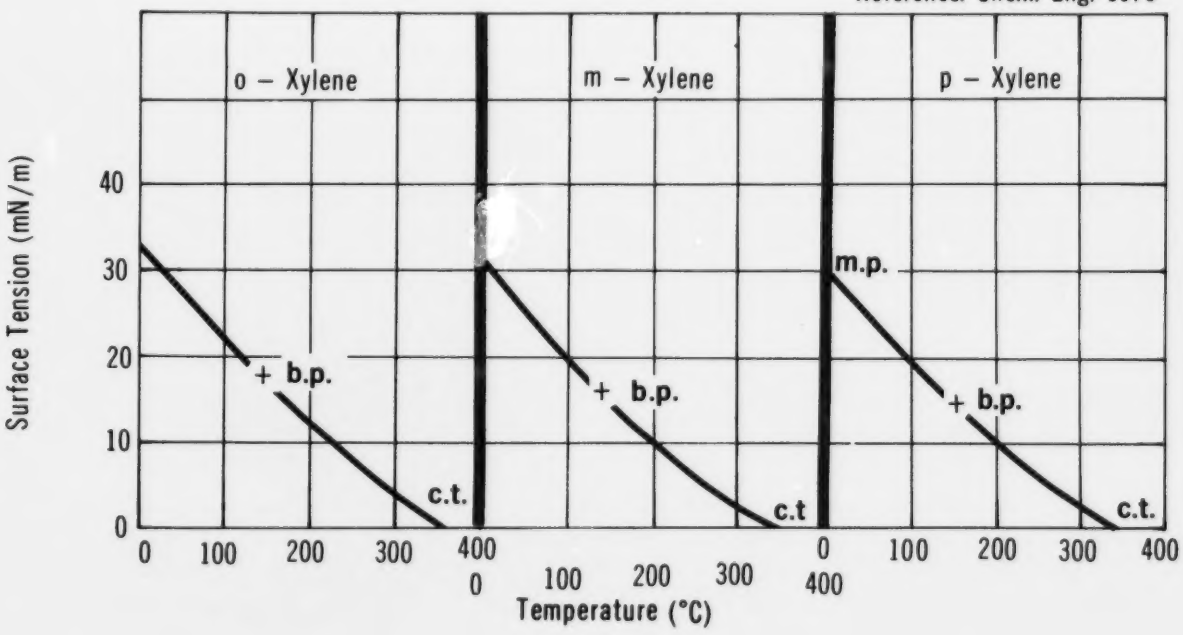


FIGURE 4

XYLENES

VAPOUR VISCOSITY vs TEMPERATURE

Reference: Chem. Eng. 1975

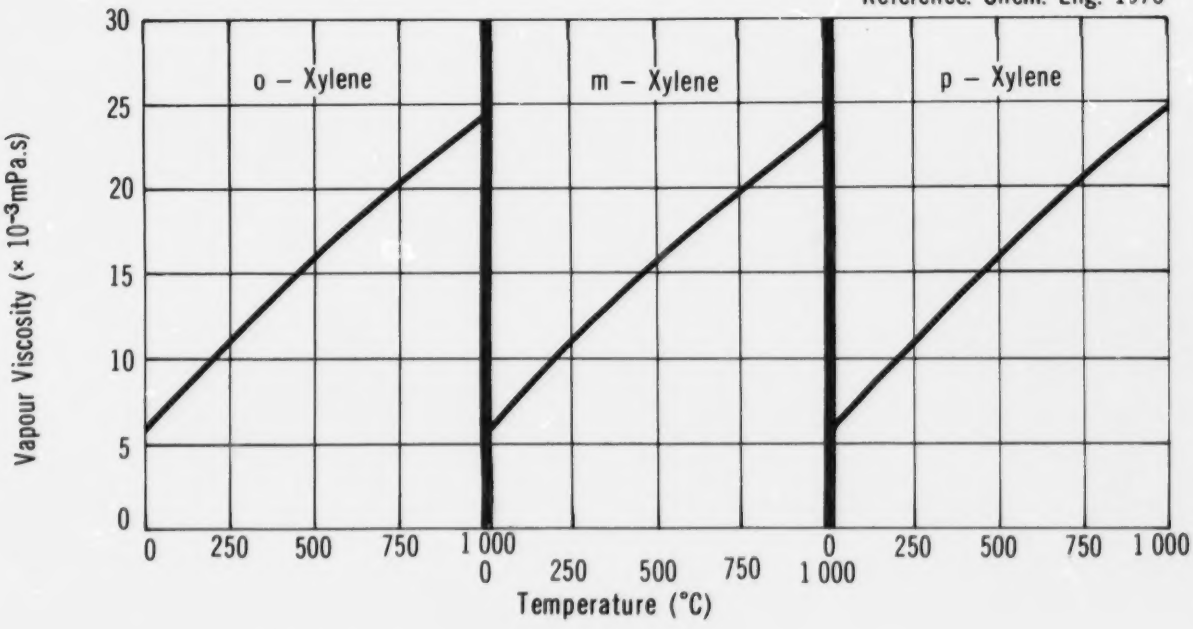


FIGURE 5

LIQUID VISCOSITY vs TEMPERATURE

Reference: Chem. Eng. 1975

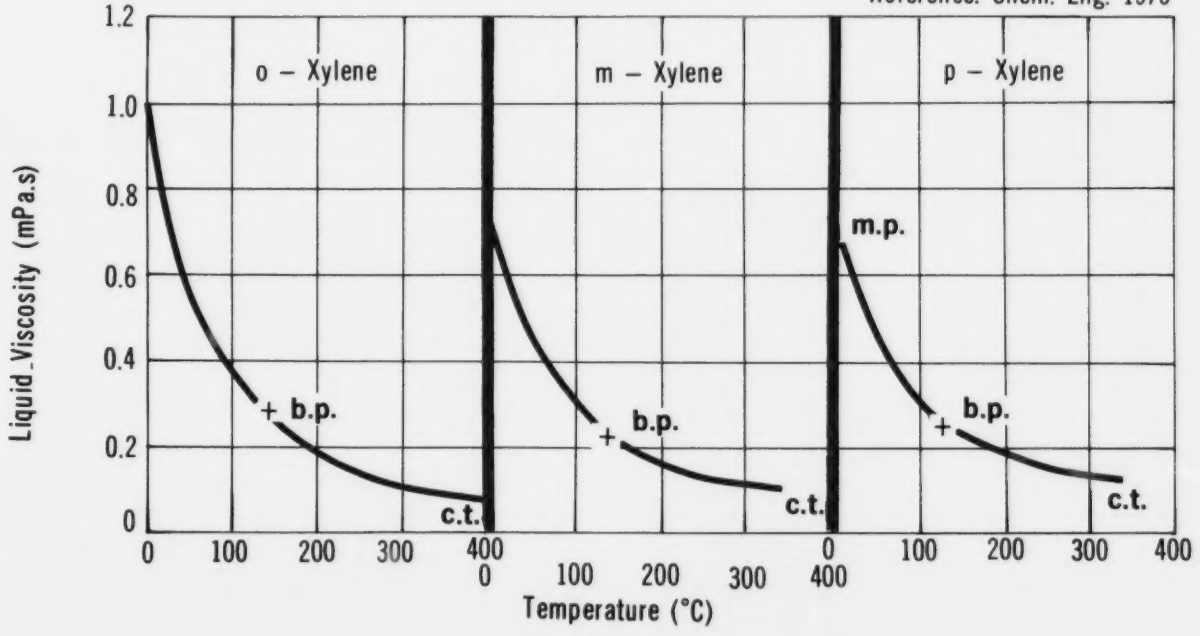
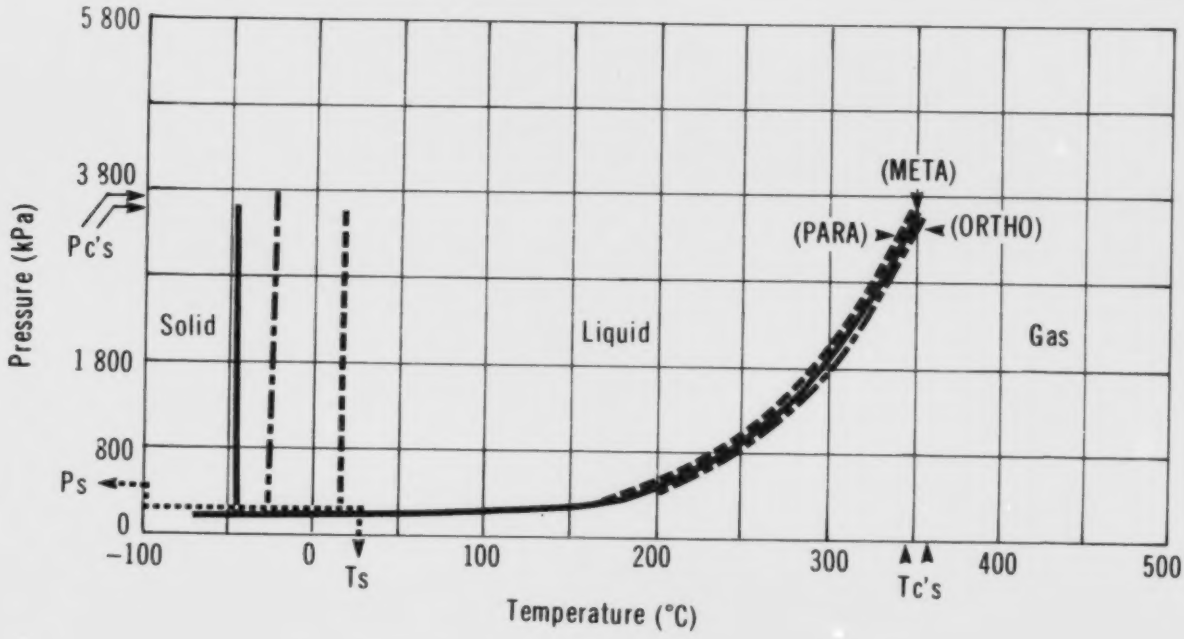


FIGURE 6

XYLENES

PHASE DIAGRAM



3 COMMERCE AND PRODUCTION

3.1 Grades, Purities (ISH 1977; Ullmann 1983; Corpus 1983; Hancock 1982)

Xylenes are sold in a variety of grades. The most common grade in Canada is the solvent grade or "mixed xylenes" which is a mixture of the three isomers along with ethylbenzene. A similar grade but with a large portion of the ortho isomer removed is also available and is usually known as "ortho-depleted". The typical composition of these two grades is shown below:

	Mixed xylenes (solvent grade)		Ortho-depleted (solvent grade)
m-Xylene (percent)	40-60	(typ. 42)	50-70
o-Xylene (percent)	10-20	(typ. 20)	1-10
p-Xylene (percent)	10-20	(typ. 18)	20-30
Ethylbenzene (percent)	15-20	(typ. 15)	2-15
Total Xylenes (percent)	>84		>90
Density (15.5°C)	0.865-0.875		0.865-0.880

Xylene isomers are occasionally sold separately in a variety of grades as research, pure, commercial, and technical. The typical composition is given below (as mass percentage):

	Research Grade	Pure Grade	Technical Grade	Commercial Grade
o-Xylene				
o-Xylene (percent)	99.99	99.7		95-96.5
m-Xylene (percent)	0.01	0.3		
Density (15.5°C)	0.8848	0.885		0.882-0.8838
***m*-Xylene**				
m-Xylene (percent	99.99	99.9	99.2	95.4
p-Xylene (percent)	0.01	0.1	0.4	0.4
o-Xylene (percent)	-	-	0.3	2
Ethylbenzene (percent)	-	-	0.1	2
Density (15.5°C)	0.8687	0.869	0.869	0.869

	Research Grade	Pure Grade	Technical Grade	Commercial Grade
p-Xylene				
p-Xylene (percent)	99.99	99.8	99.0	99.1-99.3
m-Xylene (percent)	0.01	0.2	0.6	max. 0.8
o-Xylene (percent)	-	trace	0.4	-
Density (15.5°C)	0.8657	0.866	0.866	0.865-0.866

3.2 **Domestic Manufacturers** (Corpus 1983; CBG 1980; Scott 1979)

These are corporate headquarters' addresses and are not intended as spill response contacts.

Domtar Inc.
C.P. 7212, Succ A
395 Boul de Maisonneuve O.
Montreal, Quebec
H3C 3M3
(514) 282-5400

Esso Chemical Canada
2300 Yonge Street
Toronto, Ontario
M5W 1K3
(416) 488-6600

Petrocan Chemicals
1 Place Ville-Marie
Montreal, Quebec
H3B 4A9
(514) 866-3911
(514) 866-2094

Petrosar
785 Hill Street
P.O. Box 7000
Coronna, Ontario
N0N 1G0
(519) 862-2911

Shell Canada
505 University Avenue
Toronto, Ontario
M5G 1X4
(416) 866-7111
(514) 866-2094

Sunchem, Division of
Sunoco Inc.
56 Wellesley Street West
Toronto, Ontario
M5S 2S4
(416) 924-4111

Texaco Canada
90 Wynford Drive
Don Mills, Ontario
M3C 1K4
(416) 443-7811

3.3 Other Suppliers (CBG 1980; Corpus 1983; Scott 1979)

Anachemia Ltd.
P.O. Box 147
Lachine, Quebec
H8S 4A7
(514) 489-5711

Apco Industries Co. Ltd.
10 Industrial Street
Toronto, Ontario
M4G 1Z1
(416) 421-6161

Arliss Chemicals Co. Inc.
325 Hymus Blvd
Pointe Claire, Quebec
H9R 1G8
(514) 694-2170

Ashland Chemicals
Division Valvoline Oil & Chem.
150 Bronco Avenue
Toronto, Ontario
M6E 4Y1
(416) 651-2822

Bate Chemical Co. Ltd.
160 Lesmill Road
Don Mills, Ontario
M3B 2T7
(416) 445-7050

Canada Colours and Chemicals Ltd.
80 Scarsdale Road
Don Mills, Ontario
M3B 2R7
(416) 924-6831

Cote Chemicals Inc.
111 Bombardier Park
Chateauguay Centre, Quebec
J6J 3X0
(514) 691-6260

Dominion Cisco Industries Ltd.
84 Signet Drive
Weston, Ontario
M9L 1T2
(416) 528-7941

Gulf Canada Products Co.
800 Bay Street
Toronto, Ontario
M5S 1Y8
(416) 924-4141

Harrison & Crosfield (Canada) Ltd.
Toronto, Ontario
M4H 1G1
(416) 425-6500

International Chemical Canada Ltd.
P.O. Box 385
Brampton, Ontario
L6V 2L3
(416) 453-4234

Paisley Products of Canada Ltd.
40 Upton Road
Scarborough, Ontario
M1L 2B8
(416) 755-2216

Recochem Inc.
850 Montee De Liesse
Montreal, Quebec
H9S 1H7
(514) 341-3550

Shefford Chemicals Ltd.
1028 Principale
Granby, Quebec
J2G 8C8
(514) 378-0125

PPG Industries Ltd.
Stanchem Division
5029 St. Ambroise Street
Montreal, Quebec
(514) 933-6721

Syndel Laboratories Ltd.
8879 Selkirk Street
Vancouver, British Columbia
V6P 4J6
(604) 266-7131

Van Waters & Rogers Ltd.
9800 Van Horne Way
Richmond, British Columbia
V6X 1W5
(604) 274-1441

Wilchem Ltd.
P.O. Box 57, Station A
Willowdale, Ontario
M2N 5S7
(416) 222-2038

3.4 Major Transportation Routes

Current Canadian production of xylene is located primarily in Ontario, in Sarnia, Corunna, Mississauga and Hamilton (63 percent of total capacity), and in Montreal, Quebec (35 percent of total production). A smaller production facility is also located in Ioco, British Columbia. The major market area for xylene is in Ontario and Quebec. The product is shipped by rail tank cars, tank trucks, and in drums.

3.5 Production Levels (Corpus 1983)

Company, Plant Location		Nameplate Capacity kilotonnes/yr (1982)
Domtar, Hamilton, Ont.		3
Esso Chemical Canada, Ioco, B.C.		6
Esso Chemical Canada, Sarnia, Ont.		22
Petrocan Chemicals, Montreal, Que.		175
Petrosar, Corunna, Ontario		50
Shell Canada, Corunna, Ont.		60
Sunchem, Sarnia, Ont.		170
Texaco Canada, Mississauga, Ont.		12
	TOTAL	498
Domestic Production (1982)		414.5
Imports (1982)		0.2
	TOTAL SUPPLY	414.7

3.6 Manufacture of Xylenes (FKC 1975; Hancock 1982)

3.6.1 General. Xylenes are produced in Canada by the catalytic reforming of naphthene-rich fractions of naphtha feedstocks, usually in conjunction with benzene and/or toluene production.

3.6.2 Manufacturing Process. The feedstock is preheated in heat exchangers, vaporized at 565°C, and mixed with hydrogen-rich recycle gas. The mixture is passed through a reforming reactor containing a molybdenum oxide-alumina catalyst for about 15 s:

$$\text{naphthenes} \xrightarrow[565°C;\ 1000 \text{ to } 2000 \text{ kPa}]{} C_8H_{10} + XH_2$$

This is followed by a heat exchanger where liquids are separated from the gas stream. The liquid is fractionated; the xylene fraction is purified by combinations of distillation, solvent extraction, and low temperature crystallization processes.

Separation of isomers by absorption, fractional crystallization/solvent extraction, complex formation and separation, clathrate formation or chemical modifications may be done.

3.7 **Major Uses in Canada** (Corpus 1983; Kirk-Othmer 1984)

Xylenes are used for production of phthalic anhydride, adhesives, coatings, inks, dyes and solvents. *p*-Xylene is oxidized to terephthalic acid or dimethyl terephthalate as a first step in polyester production. *o*-Xylene is oxidized to phthalic anhydride which is converted to plasticizers. *m*-Xylene is oxidized to isophthalic acid for use in polyesters. In 1982, 85 percent of domestic production was exported, 10 percent was used as solvents and 4 percent was used in the production of phthalic anhydride.

3.8 **Major Buyers in Canada** (Corpus 1983)

Almatex, London, Ont.
Anachemia Chemicals, Montreal, Que.
BASF Canada, Cornwall, Ont.
Bate Chemical, Toronto, Ont.
Borden Chemical, Toronto, Ont.
Canada Colors & Chemical, Don Mills, Ont.
C-I-L Paints, Toronto, Ont.
Color Your World, Toronto, Ont.
Cote Chemicals, Chateauguay, Que.
DeSoto Coatings, Toronto, Ont.
Du Pont Canada, Ajax, Ont.
Emchem Sales, Vancouver, B.C.
Ford Motor Canada, Oakville, Ont.
General Motors Canada, Oshawa, Ont.
Glidden (Sico), Toronto, Brampton, Ont.
Gulf Canada, Montreal, Que.
Harrison & Crosfield, Toronto, Ont.
Hart Chemical, Guelph, Ont.
Industrial Adhesives, Toronto, Ont.; Montreal, Que.
Inmont Canada, Toronto, Brantford, Ont.
International Paints, Montreal, Que.
Lawter Chemicals Canada, Toronto, Ont.
3M, London, Ont.
Mobil Chemical, Toronto, Ont.
PPG Industries Canada, Toronto, Ont.
Shefford Chemicals, Granby, Que.
Sherwin-Williams Canada, Montreal, Que.
Sico, Quebec City, Montreal, Que.

Sinclair & Valentine, Toronto, Ont.
Stranchem (PPG), Montreal, Que.
Toronto Star, Toronto, Ont.
USM Canada, Montreal, Que.
Van Waters & Rogers, Vancouver, B.C.; Montreal, Que.

4 MATERIAL HANDLING AND COMPATIBILITY

4.1 Containers and Transportation Vessels

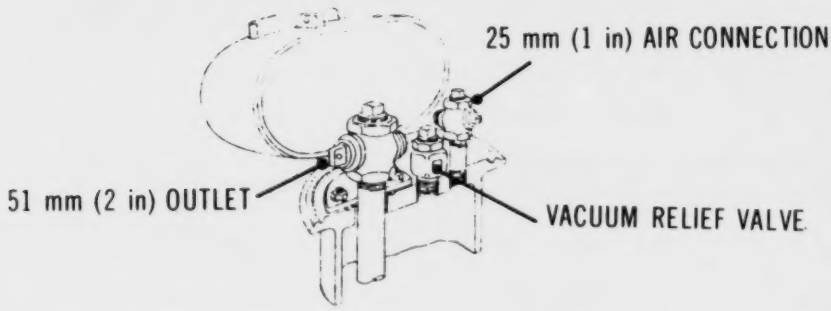
4.1.1 Bulk Shipment. Transportation vessels and containers under this category have been grouped under the classifications of railway tank cars and highway tank vehicles.

4.1.1.1 Railway tank cars. Railway tank cars used to transport xylenes are described in Table 2 (TCM 1979). Figure 7 shows a 111A60W1 railway car typically used to transport xylenes; Table 3 indicates railway tank car details associated with this drawing (TCM 1979; RTDCR 1974). This particular car may be insulated and steam-coiled for cold winter conditions. Xylenes may freeze, depending on the composition of the mixture from the ortho, meta and para isomers (Petrofina MSDS 1978). Cars are equipped for unloading by gravity flow through a 152 mm (6 in.) diameter bottom outlet provided with an inner plug valve (TDGC 1980). In addition to bottom unloading, the cars may be unloaded from the top by pump. In this case, the liquid is withdrawn through an eduction pipe which extends from the bottom of the tank to the top operating platform where it terminates with an unloading connection valve. Air pressure is never used for unloading xylene tanks (PC 1981).

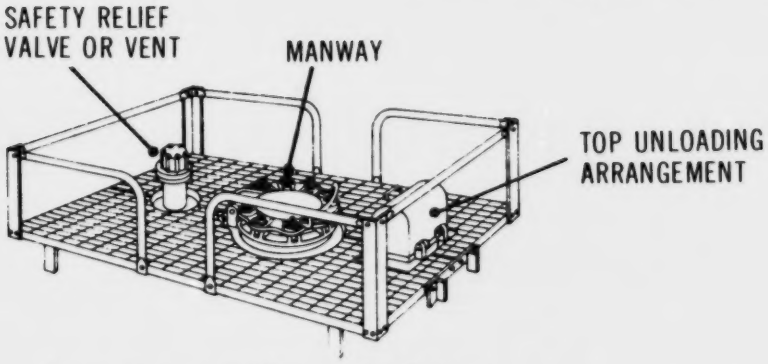
TABLE 2 RAILWAY TANK CAR SPECIFICATIONS

CTC/DOT* Specification Number	Description
111A60W1	Steel fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Test pressure 414 kPa (60 psi).
111A60F1	Steel forge-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Test pressure 414 kPa (60 psi).
111A100W1	Steel fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Bottom outlet or washout optional. Test pressure 690 kPa (100 psi).

* Canadian Transport Commission and Department of Transportation (U.S.)



Detail of top unloading arrangement



Detail of loading platform

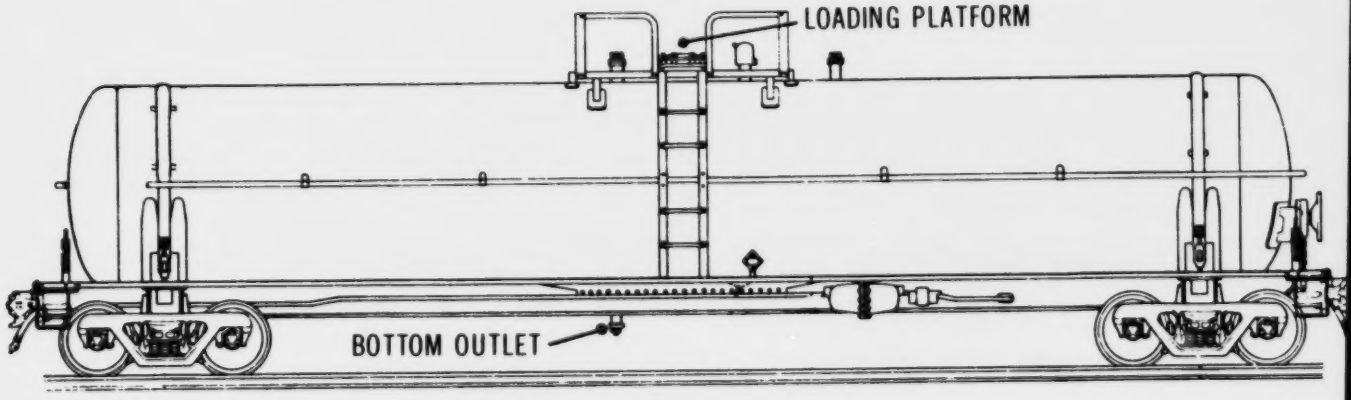


Illustration of tank car layout

TABLE 3 TYPICAL RAILWAY TANK CAR SPECIFICATIONS - CLASS 111A60W1 (TCM 1979; RTDCR 1974)

Description	Tank Car Size (Imp. Gal.) 16 700		17 200		20 000	
Overall						
Nominal capacity	75 700 L	(16 700 gal.)	78 000 L	(17 200 gal.)	90 900 L	(20 000 gal.)
Car weight - empty	33 900 kg	(74 700 lb.)	33 900 kg	(74 700 lb.)	38 900 kg	(85 800 lb.)
Car weight - (max.)	119 000 kg	(263 000 lb.)	83 500 kg	(184 000 lb.)	119 000 kg	(263 300 lb.)
Tank						
Material	Steel		Steel		Steel	
Thickness	11.1 mm	(7/16 in.)	11.1 mm	(7/16 in.)	11.1 mm	(7/16 in.)
Inside diameter	2.60 m	(102 in.)	2.62 m	(103 in.)	2.74 m	(108 in.)
Test pressure	414 kPa	(60 psi)	414 kPa	(60 psi)	414 kPa	(60 psi)
Burst pressure	1640 kPa	(240 psi)	1640 kPa	(240 psi)	1640 kPa	(240 psi)
Approximate Dimensions						
Coupled length	17 m	(57 ft.)	17 m	(57 ft.)	18 m	(60 ft.)
Length over strikers	16 m	(53 ft.)	16 m	(53 ft.)	17 m	(57 ft.)
Length of truck centres	13 m	(42 ft.)	13 m	(42 ft.)	14 m	(45 ft.)
Height to top of grating	4 m	(12 ft.)	4 m	(12 ft.)	4 m	(13 ft.)
Overall height	5 m	(15 ft.)	5 m	(15 ft.)	5 m	(15 ft.)
Overall width (over grabs)	3.2 m	(127 in.)	3.2 m	(127 in.)	3.2 m	(127 in.)
Length of grating	2-3 m	(8-10 ft.)	2-3 m	(8-10 ft.)	2-3 m	(8-10 ft.)
Width of grating	1.5-2 m	(5-6 ft.)	1.5-2 m	(5-6 ft.)	1.5-2 m	(5-6 ft.)
Loading/Unloading Fixtures						
Top Unloading						
Unloading connection	51 mm	(2 in.)	51 mm	(2 in.)	51 mm	(2 in.)
Manway/fill hole	203-356 mm	(8-14 in.)	203-356 mm	(8-14 in.)	203-356 mm	(8-14 in.)
Air connection	25-51 mm	(1-2 in.)	25-51 mm	(1-2 in.)	25-51 mm	(1-2 in.)
Bottom Unloading						
Bottom outlet	102-152 mm	(4-6 in.)	102-152 mm	(4-6 in.)	102-152 mm	(4-6 in.)
Safety Devices	Safety vent or valve					
Dome	None					
Insulation	Optional					

4.1.1.2 Tank motor vehicles. Xylenes are transported by tank motor vehicles with tanks classed as nonpressure vessels. Design pressure for such tanks must not exceed 101 kPa (15 psi). Motor vehicle tanks are similar to the railway tanks previously described. These highway tankers are usually unloaded by pump from the top unloading connection valve (PC 1981).

The off-loading equipment and procedures for tank motor vehicles are similar to those for railway tank cars, to be discussed later.

4.1.2 Packaging. Xylenes, in addition to railway bulk shipments, are also transported in drums. Drums fabricated from a variety of construction materials are permitted. Table 4 describes these drums (TDGC 1980). Small containers such as cans and bottles are used to transport small quantities.

TABLE 4 DRUMS

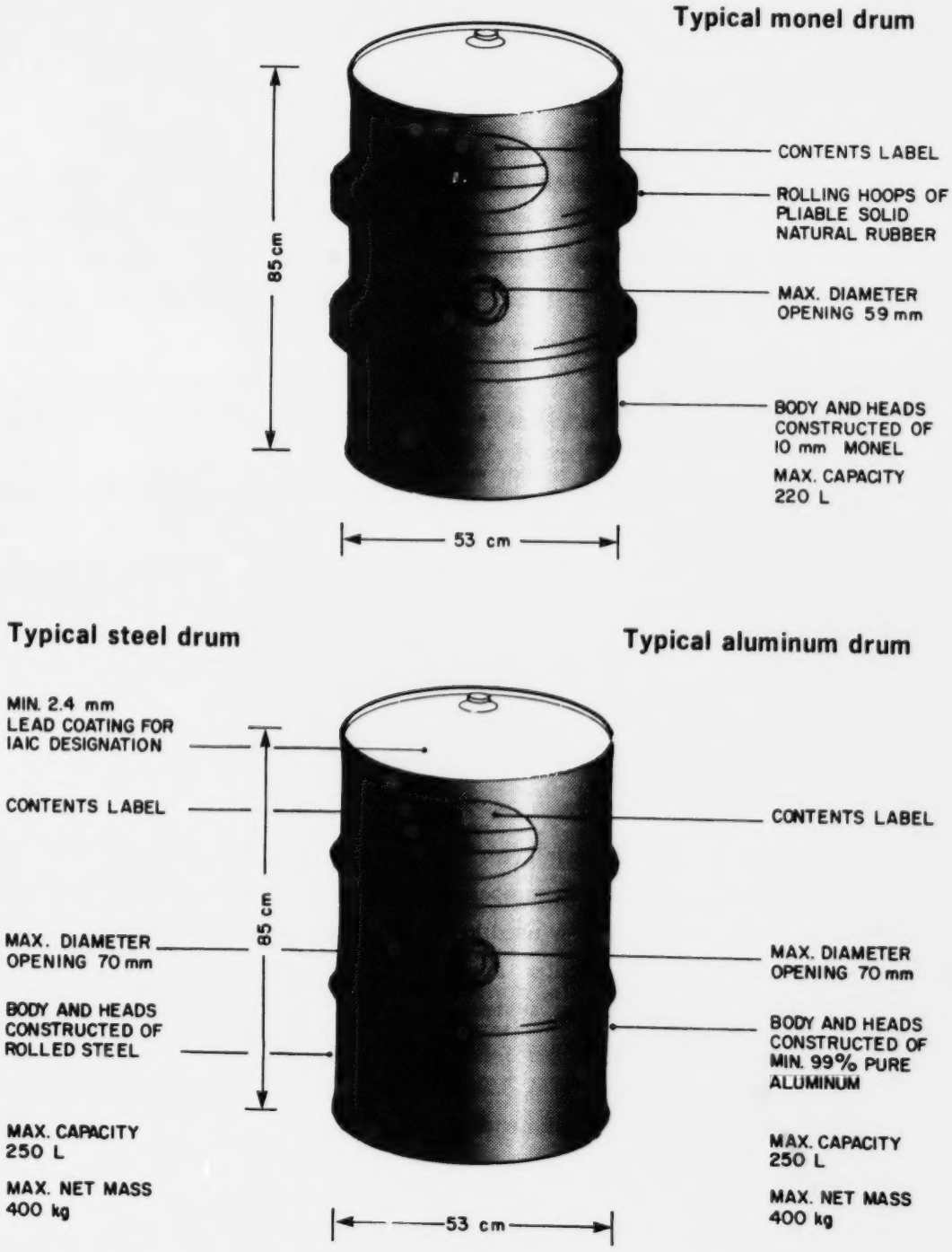
Type of Drum	Designation	Description	Figure No. (If any)
Steel	1A1	Nonremovable head, reusable	8
	1A1A	1A1 with reinforced chime	8
	1A1B	1A1 with welded closure flange	8
	1A1D	1A1 with coating (other than lead)	8
	1A2	Removable head, reusable	8
	1A3	Nonremovable head, single use only	8
Monel*	TC5M		8
Aluminum	1B1	Nonremovable head	8
	1B2	Removable head	8
Steel Drums with inner plastic receptacles	6HA1	Outer steel sheet in the shape of drum. Inner plastic receptacle. Maximum capacity of 225 L (49 gal.)	
Fibreboard Drums with inner plastic receptacles	6HG1	Outer containers of convolutely wound plies of fibreboard. Inner plastic in shape of drum. Maximum capacity of 225 L (49 gal.)	

* See Section 4.3 of this report.

FIGURE 8

XYLENES

TYPICAL DRUM CONTAINERS


Typical monel drum
CONTENTS LABEL
ROLLING HOOPS OF PLIABLE SOLID NATURAL RUBBER
MAX. DIAMETER OPENING 59 mm
BODY AND HEADS CONSTRUCTED OF 10 mm MONEL
MAX. CAPACITY 220 L
85 cm
53 cm
Typical steel drum
MIN. 2.4 mm LEAD COATING FOR IAIC DESIGNATION
CONTENTS LABEL
MAX. DIAMETER OPENING 70 mm
BODY AND HEADS CONSTRUCTED OF ROLLED STEEL
MAX. CAPACITY 250 L
MAX. NET MASS 400 kg
85 cm
53 cm
Typical aluminum drum
CONTENTS LABEL
MAX. DIAMETER OPENING 70 mm
BODY AND HEADS CONSTRUCTED OF MIN. 99% PURE ALUMINUM
MAX. CAPACITY 250 L
MAX. NET MASS 400 kg

4.2 Off-loading

4.2.1 Off-loading Equipment and Procedures for Railway Tank Cars. Prior to off-loading, certain precautions must be taken (PC 1981):

- The vented storage tank must be checked to make sure that it will hold the contents of the car.
- For night-time unloading, lights must have an explosion-proof rating.
- Personnel must not enter the car under any circumstances.
- Brakes must be set, wheels chocked, derails placed and caution signs displayed.
- A safe operating platform must be provided at the unloading point.
- Tools used during unloading must be spark-resistant.
- Effectively ground the tank car.

Two means of off-loading are used for xylene rail cars, top off-loading and bottom off-loading (PC 1981).

Proceed with top off-loading as follows:

- Relieve the tank of internal vapour pressure by cooling the tank with water or venting the tank at short intervals.
- After removing the protective housing from the discharge line at the top of the car, connect the 51 mm (2 in.) unloading line.
- Off-load the tanker by pump only.

Proceed with bottom off-loading in the following manner using gravity flow:

- Relieve internal pressure as previously mentioned.
- After connecting the unloading line to the 152 mm (6 in.) bottom outlet, open the inside bottom valve by turning the valve rod handle at the top of the car.
- Off-load the car by gravity.

4.2.2 Specifications and Materials for Off-loading Equipment. The materials of construction for off-loading system components discussed in this section along with specifications refer to those generally used in xylene service. It is recognized that other materials may be used for particular applications, as indicated in Table 5. The components of a typical off-loading system that will be discussed include pipes and fittings, flexible connections, valves, gaskets and pumps.

Schedule 40 seamless ASTM A106 carbon steel pipes and fittings lined with chlorinated polyether resins are recommended for xylene lines (Dow PPS 1972). Flanged

joints should be used and these should be welded, because threaded pipes and fittings tend to leak after a very short time. Stress relief at the weld will also lengthen the serviceability of the pipes. The pipeline should be tested with air at pressures from 345 to 518 kPa (50-75 psi) and all leaks carefully stopped. If leaks develop in service, the only satisfactory way to repair them is to chip out the bad weld and reweld, or to replace the section of pipe.

The unloading line should be 51 mm (2 in.) pipe because this is the standard fitting on liquid tank cars; however, process pipe may be almost any size. Pipe under 25 mm (1 in.), however, is not recommended. Outdoor lines must be self-draining.

Flexible bellows-type expansion joints should be used for the flexible sections of the unloading line. They are manufactured with ASA ductile iron flanges with expansion members molded from tetrafluoroethylene resin (Dow PPS 1972). Some installations of flexible line are made with standard lined fittings using a number of flanged elbows.

For valving, cast iron or cast steel diaphragm valves lined with chlorinated polyether or polyvinylidene chloride resin will serve adequately (DPLV 1972). Viton may be used as a gasket material at normal temperature ranges.

A single-suction, sealless magnetic drive centrifugal pump with "wet end" material of 316 stainless steel gives good results. Leakage from this type of pump is virtually eliminated. Provision must be made for draining the pump so that repairs can be made safely (PC 1981).

Pumps should be equipped with flanges at both suction and discharge openings; screw connections are more subject to leakage and should be avoided. Centrifugal pumps should be shaft-grounded to minimize static build-up (CCPA 1983).

4.3 Compatibility with Materials of Construction

The compatibility of xylenes with materials of construction is indicated in Table 5. The unbracketed abbreviations are described in Table 6. The rating system for this report is briefly described below:

Recommended:	This material will perform satisfactorily in the given application.
Conditional:	Material will show deterioration in the given application; however, it may be suitable for intermittent or short-term service.
Not Recommended:	Material will be severely affected in this application and should not be used.

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

Application	Temp. (°C)	Material of Construction		
		Recommended	Conditional	Not Recommended
1. Pipes and Fittings	23			PVC I PVC II (DPPED 1967)
	24	Chlorinated Polyether PP PVDC (DCRG 1978)		
	93	PVDF (DCRG 1978)		ABS PE (MWPP 1978)
2. Pumps	38	GRP with FPM "O" Ring Bronze Fitted or All Iron SS 304 SS 316 (HIS 1969)		
3. Others	22			PVC, CPVC (TPS 1978)
	23		PP (TPS 1978)	
	49			PP (TPS 1978)
	66	PVDF (TPS 1978)		NR, SBR CR, NBR IIR, CSM EPDM (GPP)
	24-100	Glass (CDS 1967)		
	24			Concrete (CDS 1967)

TABLE 6 MATERIALS OF CONSTRUCTION

Abbreviation	Material of Construction
ABS	Acrylonitrile Butadiene Styrene
	Aluminum
	Bronze
	Carbon Steel
	Chlorinated Polyether
CPVC	Chlorinated Polyvinyl Chloride
CR	Polychloroprene (Neoprene)
CSM	Chlorosulphonated Polyethylene (Hypalon)
EPDM	Ethylene Propylene Rubber
FPM	Fluorine Rubber (Viton)
	Glass
GRP	Glass Reinforced Vinyl Ester
	Iron
IIR	Isobutylene/Isoprene (Butyl) Rubber
NBR	Acrylonitrile/Butadiene (Nitrile, Buna N) Rubber
NR	Natural Rubber
PE	Polyethylene
PP	Polypropylene
PVC (Followed by grade if any)	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride
PVDF	Polyvinylidene Fluoride
SBR	Styrene/Butadiene (GR-5, Buna S) Rubber
SS (Followed by grade)	Stainless Steel

5 CONTAMINANT TRANSPORT

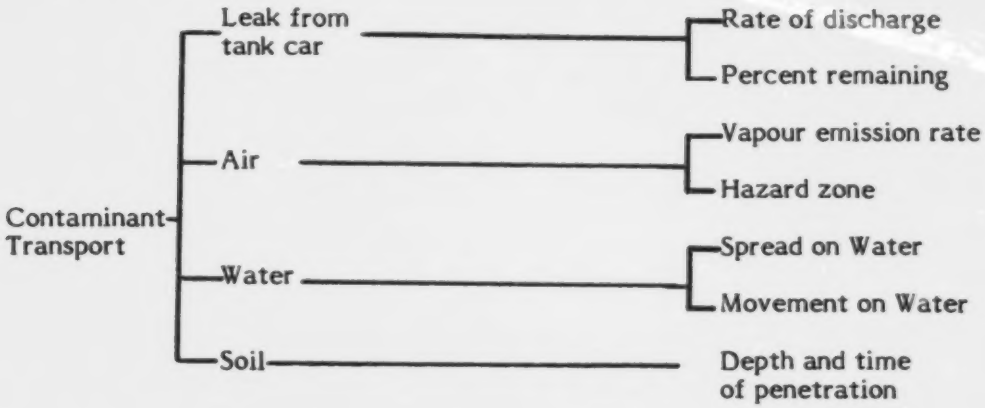
5.1 General Summary

Xylenes are relatively volatile liquids that are commonly transported in railway tank cars. When spilled in the environment, they will form a liquid pool, spreading on the surface of a water body or on the ground, being absorbed into the soil. The irritating flammable vapour is released continuously to the atmosphere by evaporation.

When spilled on water, the slick has a natural tendency to spread. Xylenes have a low solubility in water and thus will not appreciably mix.

Xylenes when spilled on the ground are gradually absorbed into the soil at a rate dependent on the soil type and its degree of saturation with water. At the same time, the downward transport of the liquid toward the groundwater table may cause environmental problems.

The following factors are considered for the transport of a xylene spill in the air, water and soil media:



It is important to note that, because of the approximate nature of the contaminant transport calculations, the approach adopted throughout has been to use conservative estimates of critical parameters so that predictions are approaching worst case scenarios for each medium. This may require that the assumptions made for each medium be quite different and to some extent inconsistent. As well as producing worst case scenarios, this approach allows comparison of the behaviours of different chemicals under consistent assumptions.

5.2 Leak Nomograms

5.2.1 Introduction. Xylenes are commonly transported in railway tank cars as nonpressurized liquids. While the capacities of the tank cars vary widely, one tank car size has been chosen throughout for development of the leak nomograms. It is approximately 2.75 m in diameter and 13.4 m long, with a carrying capacity of about 80 000 L.

If a tank car loaded with xylene is punctured on the bottom, all of the contents will drain out by gravity. The aim of the nomograms is to provide a simple means to obtain the time history of the conditions in the tank car and the venting rate of the liquid. Because of the relatively low volatility of xylene and the fact that the tank cars are not pressurized, no leak nomograms have been prepared for vapour release from a puncture in the top of the tank.

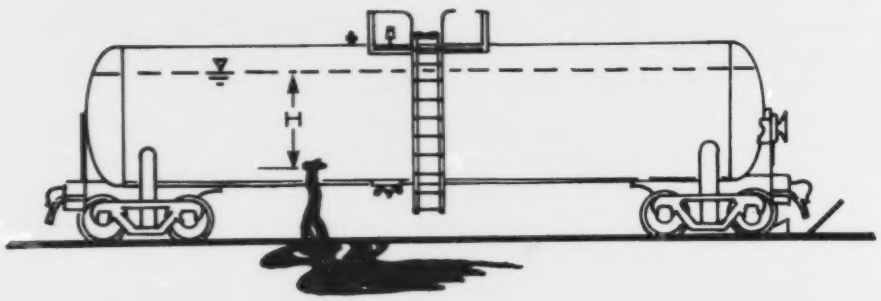


FIGURE 9 TANK CAR WITH PUNCTURE HOLE IN BOTTOM

5.2.2 Nomograms.

5.2.2.1 Figure 10: Percent remaining versus time. Figure 10 provides a means of estimating the percent of liquid remaining in the standard tank car after the time of puncture, for a number of different hole diameters. The hole diameter is actually an equivalent diameter and can be applied to a noncircular puncture.

The standard tank car (2.75 m ϕ x 13.4 m long) is assumed to be initially full (at t=0) with a volume of about 80 000 L of xylene. The amount remaining at any time (t) is not only a function of the discharge rate over time, but also of the size and shape of the tank car.

FIGURE 10

XYLENES

PERCENT REMAINING VS TIME

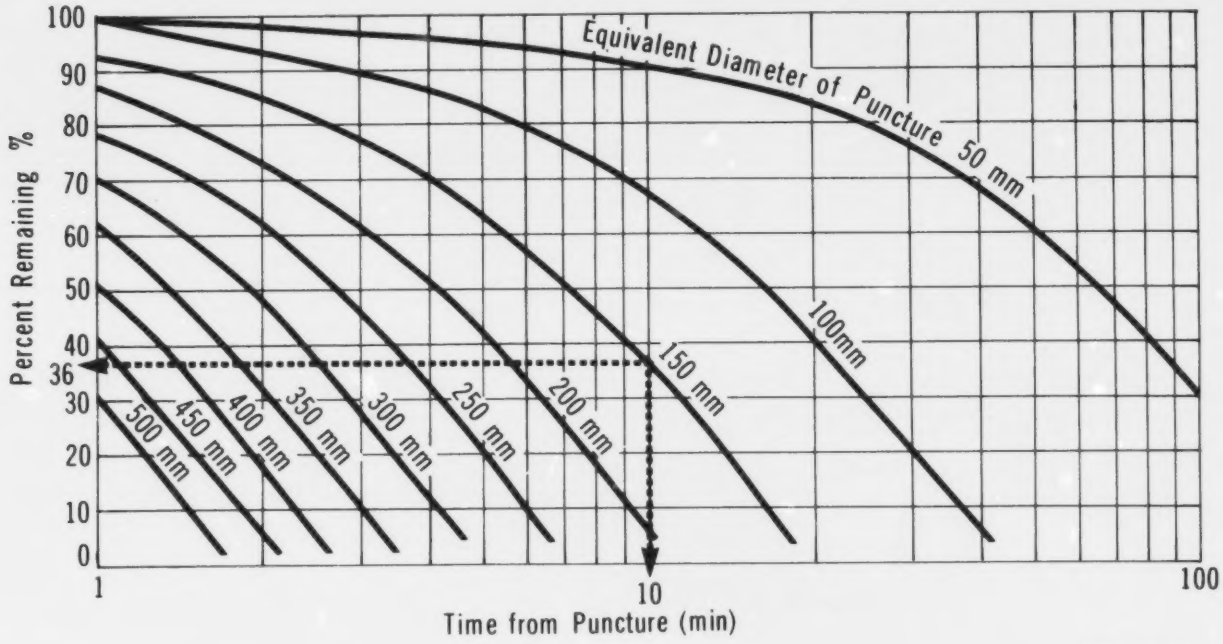
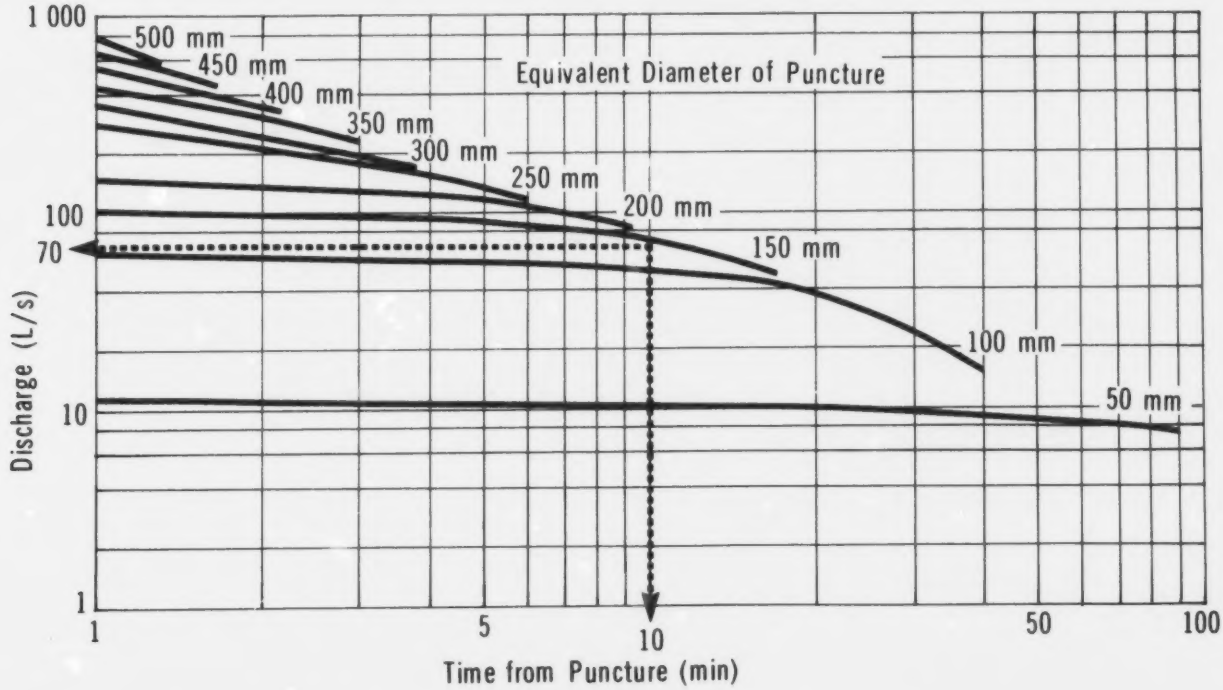


FIGURE 11

XYLENES

DISCHARGE RATE VS TIME



5.2.2.2 Figure 11: Discharge rate versus time. Figure 11 provides a means of estimating the instantaneous discharge rate (L/s) at any time (t) after the time of puncture, for a number of equivalent hole diameters. The nomogram is only applicable to the standard tank car size with an initial volume of 80 000 L.

5.2.3 Sample Calculations.

i) Problem A

The standard tank car filled with xylene has been punctured on the bottom. The equivalent diameter of the hole is 150 mm. What percent of the initial 80 000 L remains after 10 minutes?

Solution to Problem A

- Use Figure 10
- With t=10 min and d=150 mm, the amount remaining is about 36 percent or 28 800 L

ii) Problem B

With the same conditions as Problem A, what is the instantaneous discharge rate from the tank 10 minutes after the accident?

Solution to Problem B

- Use Figure 11
- With t=10 min and d=150 mm, the instantaneous discharge rate (q) = 70 L/s

5.3 Dispersion in the Air

5.3.1 Introduction. Since xylenes are relatively nonvolatile liquids, direct venting of the vapour to the atmosphere from a hole in a punctured vessel does not constitute a significant hazard downwind. Only vapour released from a liquid pool spilled on a ground or water surface is treated here.

To estimate the vapour concentrations downwind of the accident site for the determination of the flammability or toxicity hazard zone, the atmospheric transport and dispersion of the contaminant vapour must be modelled. The models used here are based on Gaussian formulations and are the ones most widely used in practice for contaminant concentration predictions. The model details are contained in the Introduction Manual.

Figure 12 depicts schematically the contaminant plume configuration from a continuous surface release. The dispersion model represents the liquid pool area source as a virtual point source (with the same vapour emission rate, Q) located 10 equivalent pool radii upwind.

5.3.2 Vapour Dispersion Nomograms and Tables. The aim of the air dispersion nomograms is to define the hazard zone due to toxicity or flammability of a vapour cloud. The following nomograms and data tables are contained in this section (to be used in order given):

Figure 14:	vapour emission rate from a liquid pool as a function of maximum pool radius
Table 7:	weather conditions
Figure 15:	normalized vapour concentration as a function of downwind distance and weather conditions
Table 8:	maximum plume hazard half-widths
Figure 18:	vapour plume travel distance as a function of time elapsed since the spill and wind speed

The flowchart given in Figure 13 outlines the steps necessary to make vapour dispersion calculations and identifies the nomograms or tables to be used. This section deals only with the portion contained within the dashed box. Data on "total liquid discharged" and "equivalent pool radius" are contained in Sections 5.2 and 5.4, respectively. A description of each vapour dispersion nomogram and its use follows.

5.3.2.1 Figure 14: Vapour emission rate versus liquid pool radius for various temperatures. An evaporation rate for xylenes (as *m*-xylene) has been calculated employing the evaporation rate equations contained in the Introduction Manual. The computed evaporation rate for *m*-xylene at 20°C and a wind speed of 4.5 m/s (16.1 km/h) is 0.40 g/(m^2s). Evaporation rates at other temperatures have been calculated using the evaporation rate equation which, at a given wind speed, is dependent on ambient temperature and the vapour pressure (Chem. Eng. 1975) of *m*-xylene at that temperature. For example, evaporation rates of 0.086 g/(m^2s) at 0°C and 0.58 g/(m^2s) at 30°C were calculated for a wind speed of 4.5 m/s.

Using Figure 21, Section 5.4, the maximum spill radius corresponding to various spill amounts of m-xylene may be determined. The resultant spill areas and the m-xylene evaporation rates provide the basis for preparation of the vapour release rate versus spill radius nomogram in Figure 14.

FIGURE 12

XYLENES

SCHEMATIC OF CONTAMINANT PLUME

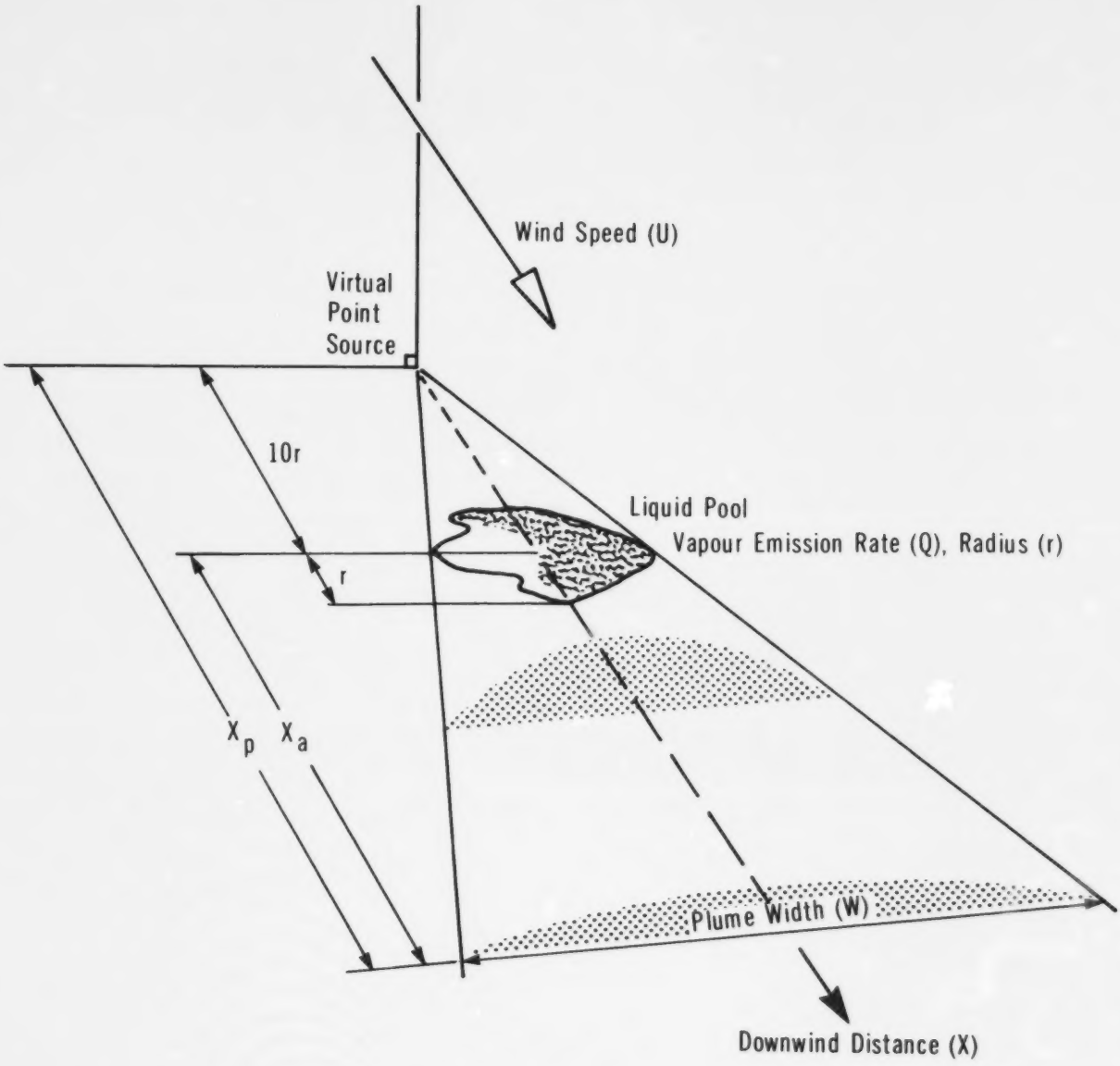


FIGURE 13

XYLENES

FLOW CHART TO DETERMINE VAPOUR HAZARD ZONE

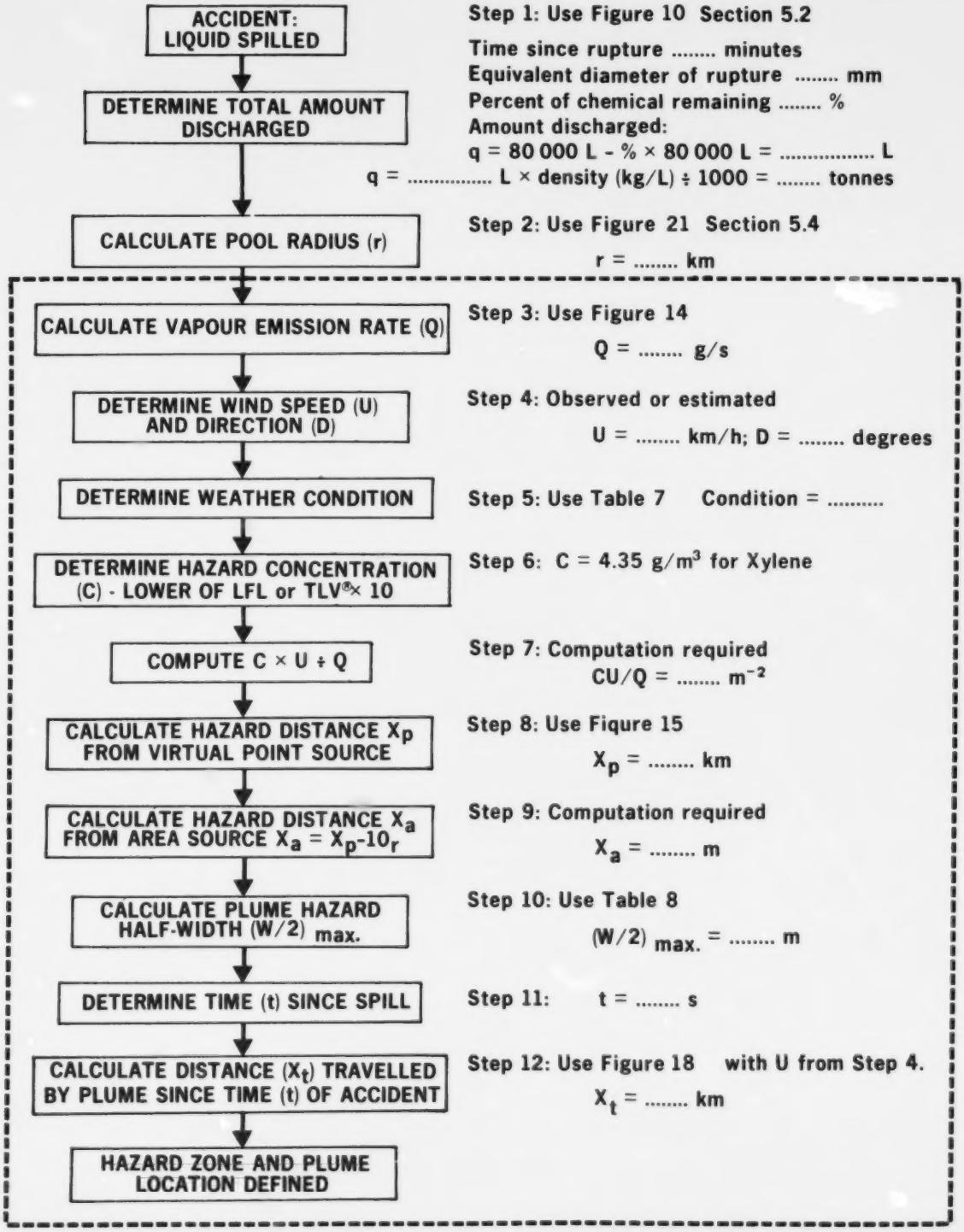
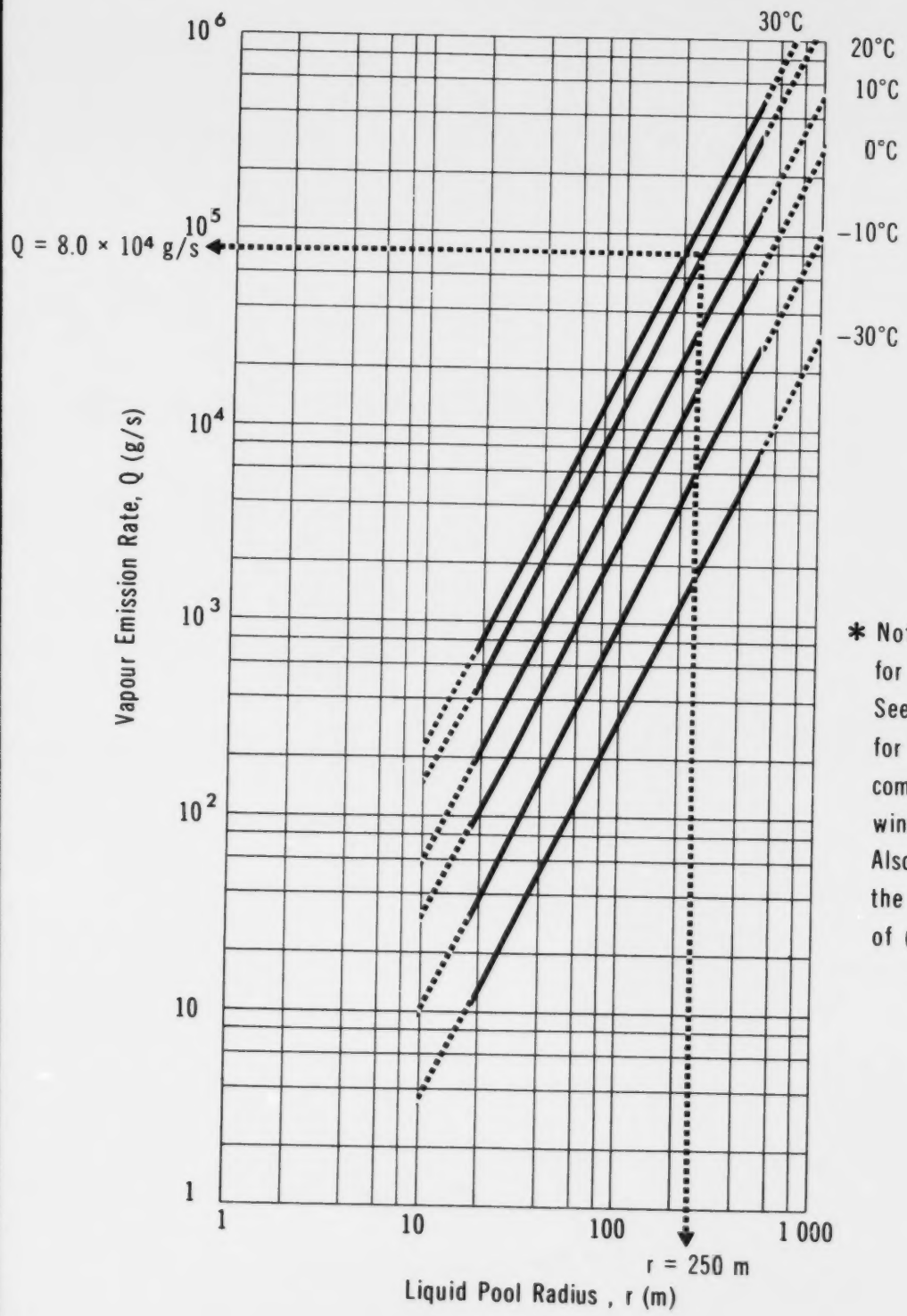

ACCIDENT: LIQUID SPILLED
DETERMINE TOTAL AMOUNT DISCHARGED
CALCULATE POOL RADIUS (r)
CALCULATE VAPOUR EMISSION RATE (Q)
DETERMINE WIND SPEED (U) AND DIRECTION (D)
DETERMINE WEATHER CONDITION
DETERMINE HAZARD CONCENTRATION (C) - LOWER OF LFL or TLV® × 10
COMPUTE C × U ÷ Q
CALCULATE HAZARD DISTANCE Xp FROM VIRTUAL POINT SOURCE
CALCULATE HAZARD DISTANCE Xa FROM AREA SOURCE Xa = Xp-10r
CALCULATE PLUME HAZARD HALF-WIDTH (W/2) max.
DETERMINE TIME (t) SINCE SPILL
CALCULATE DISTANCE (Xt) TRAVELLED BY PLUME SINCE TIME (t) OF ACCIDENT
HAZARD ZONE AND PLUME LOCATION DEFINED
Step 1: Use Figure 10 Section 5.2
Time since rupture ..... minutes
Equivalent diameter of rupture ..... mm
Percent of chemical remaining ..... %
Amount discharged:
q = 80 000 L - % × 80 000 L = ... L
q = ... L × density (kg/L) ÷ 1000 = ... tonnes
Step 2: Use Figure 21 Section 5.4
r = ... km
Step 3: Use Figure 14
Q = ... g/s
Step 4: Observed or estimated
U = ... km/h; D = ... degrees
Step 5: Use Table 7 Condition = ...
Step 6: C = 4.35 g/m3 for Xylene
Step 7: Computation required
CU/Q = ... m-2
Step 8: Use Fiqure 15
Xp = ... km
Step 9: Computation required
Xa = ... m
Step 10: Use Table 8
(W/2) max. = ... m
Step 11: t = ... s
Step 12: Use Figure 18 with U from Step 4.
Xt = ... km

FIGURE 14

XYLENES

VAPOUR EMISSION RATE VS LIQUID POOL RADIUS FOR VARIOUS TEMPERATURES



* Note: Nomogram applies for wind speed of m/s. See Introduction Manual for relationships to compute values for other wind speeds, if necessary. Also, the solid portions of the curves represent spills of 0.1 to 70 tonnes.

Use: For a pool of xylene of known radius, the rate (Q) at which xylene vapour is released to the atmosphere at a given temperature can then be estimated from Figure 14. The solid portions of the curves represent spills of 0.1 to 70 tonnes, the latter representing about one standard 80 000 L rail car load of xylene. It should be noted that Figure 14 is valid for a wind speed of 4.5 m/s (16.1 km/h) and therefore can only be used to provide an approximation of xylene vapour emission rates at other wind speeds. The Introduction Manual contains the appropriate equation to convert the evaporation rate at 4.5 m/s to an evaporation rate at another wind speed should it be desired.

It should also be noted that the determination of the emission rate is based on the spill radius on calm water (Table T1, CHRIS 1974). Since calm water represents a flat, unbounded surface compared to the type of ground surface that would normally be encountered in a spill situation (namely, irregular and porous), the spill radius on calm water is considered to provide the maximum value. Therefore, when spills on land are assessed by using the water algorithm, the spill radius would be overestimated and worst case values are provided.

TABLE 7 WEATHER CONDITIONS

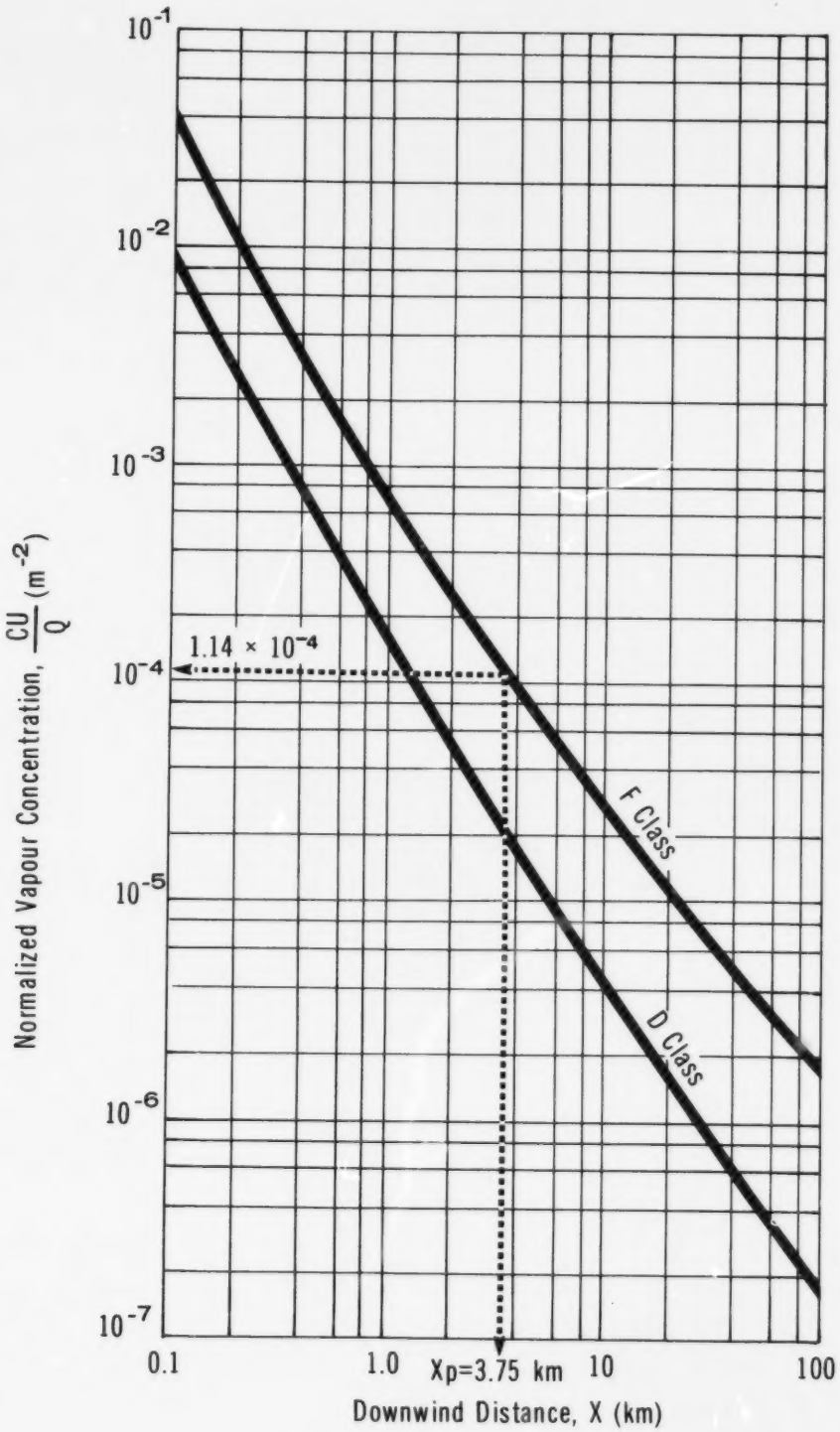
Weather Condition F	Weather Condition D
Wind speed < 11 km/h (≃ 3 m/s) and one of the following:	Most other weather conditions
- overcast day	
- night time	
- severe temperature inversion	

5.3.2.2 Figure 15: Normalized vapour concentration versus downwind distance. Figure 15 shows the relationship between the vapour concentration and the downwind distance for weather conditions D and F. The nomograms were developed using the dispersion models described in the Introduction Manual. The vapour concentration is represented by the normalized, ground-level concentration (CU/Q) at the centreline of the contaminant plume. Weather condition F is the poorest for dispersing a vapour cloud and condition D is the most common in most parts of Canada. Before using Figure 15, the weather condition must be determined from Table 7.

FIGURE 15

XYLENES

NORMALIZED VAPOUR CONCENTRATION VS DOWNWIND DISTANCE



Use: The maximum hazard distance, X_p, downwind of the spill can be calculated from Figure 15 knowing:

- Q, the vapour emission rate (g/s)
- U, the wind speed (m/s)
- the weather condition
- the hazard concentration limit, C, which is the lower value of 10 times the Threshold Limit Value• (TLV, in g/m^3) or the Lower Flammability Limit (LFL, in g/m^3). Note: To convert the TLV• (in ppm) and the LFL (in percent by volume) to concentrations in g/m^3, use Figures 16 and 17

A hazard concentration limit of 10 times the TLV• has been arbitrarily chosen as it represents a more realistic level at which there would be concern for human health on the short term (i.e., on the order of 30 minutes). The TLV• is a workplace standard for long-term exposure and use of this value as the hazard limit would result in unrealistically large hazard zones.

5.3.2.3 Table 8: Maximum plume hazard half-widths. This table presents data on the maximum plume hazard half-width, $(W/2)_{max}$, for a range of Q/U values under weather conditions D and F. These data were computed using the dispersion modelling techniques given in the Introduction Manual for a value of 10 times the xylene Threshold Limit Value (TLV•) of 0.435 g/m^3, or 4.35 g/m^3. The maximum plume hazard half-width represents the maximum half-width of the xylene vapour cloud, downwind of the spill site, corresponding to a hazard concentration limit of 10 x TLV•. Table 8 is therefore only applicable for a xylene hazard concentration limit of 10 x TLV• or 4.35 g/m^3. Also, data are provided up to a maximum hazard distance downwind of 100 km.

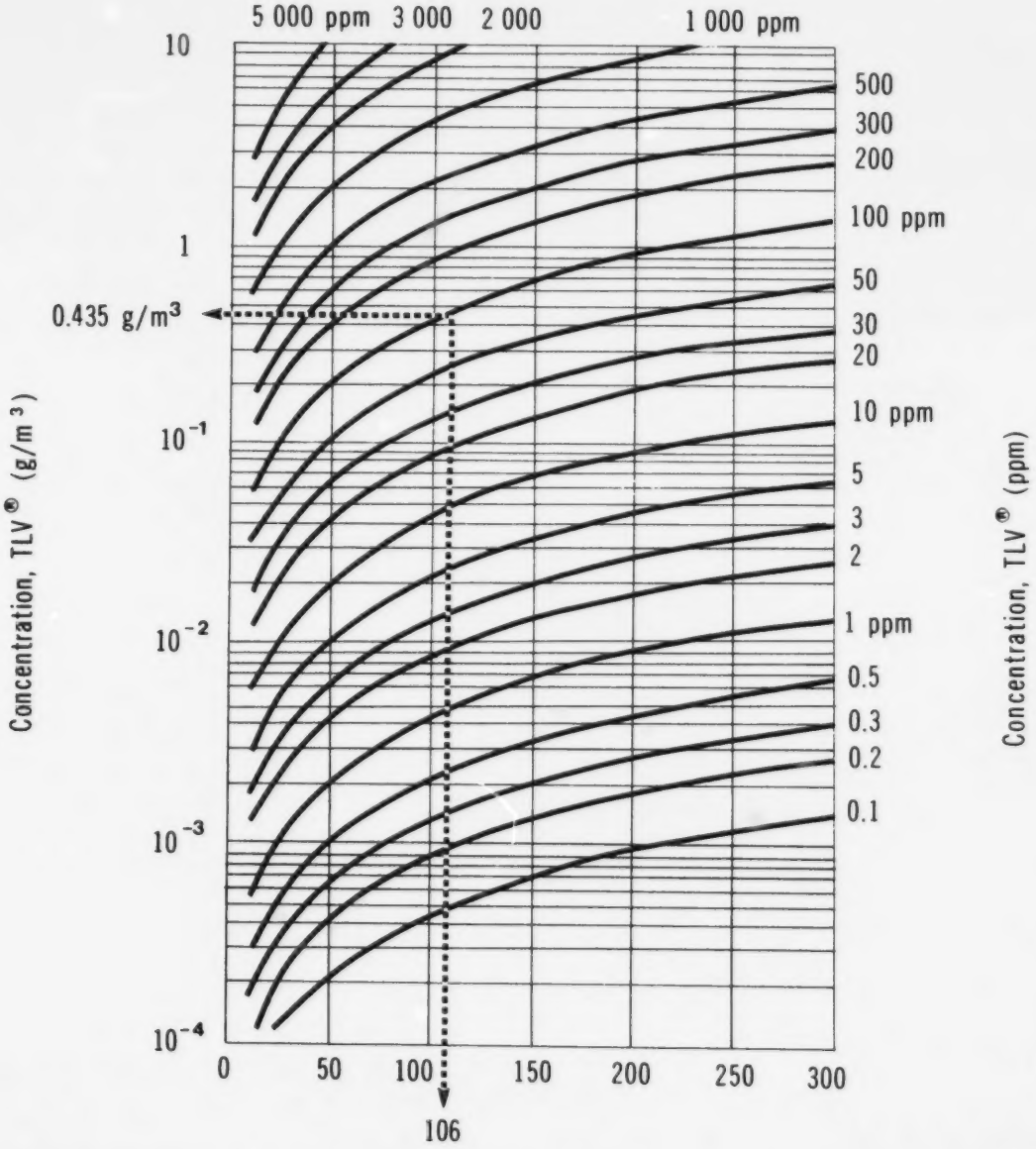
Under weather condition D, the wind speed (U) range applicable is 1 to 30 m/s. The range of vapour emission rates (Q) used was 30 000 to 30 000 000 g/s, corresponding to xylene spills in the range of about 7.5 to 5000 tonnes, respectively. If the entire contents of an 80 000 L (17 600 Imp. gal.) tank car spill, the mass spilled would be 70 000 kg or approximately 70 tonnes. Therefore, under Class D of Table 8, data are provided for up to 70 times this amount.

Under weather condition F, the wind speed (U) range applicable is 1 to 3 m/s. The range of vapour emission rates (Q) used was 3000 to 2 500 000 g/s, corresponding to xylene spills in the range of about 1 to 1000 tonnes, respectively. Therefore, under class F of Table 8, data are provided for up to 14 times a standard rail car load.

FIGURE 16

XYLENES

CONVERSION OF THRESHOLD LIMIT VALUE (TLV®) UNITS (ppm to g/m³)



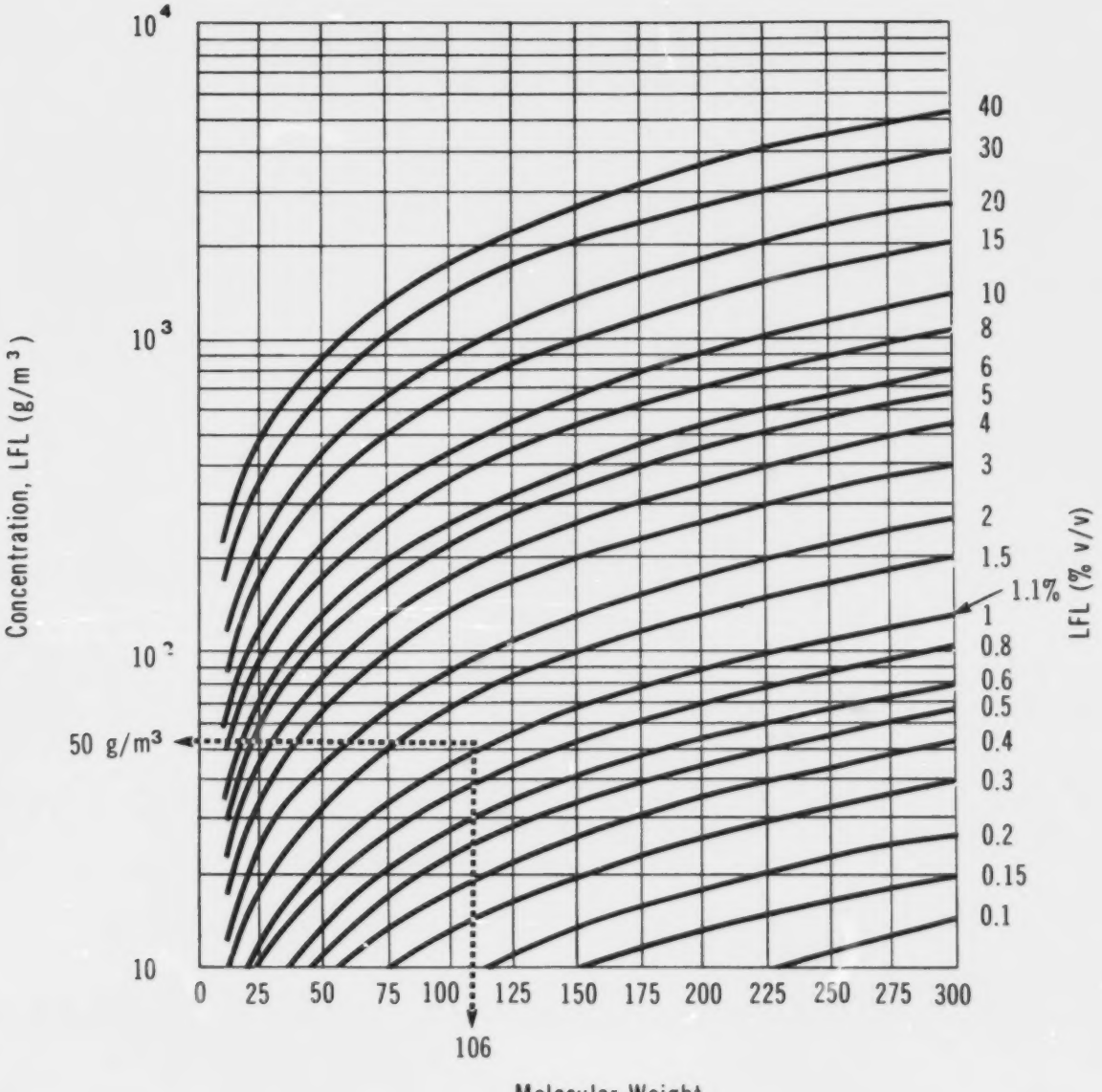
Example: Xylenes, MW = 106, TLV®= 100 ppm,
then TLV® in g/m³ = 0.435

Note: data applicable at 25°C and 760 mm Hg pressure

FIGURE 17

XYLENES

CONVERSION OF LOWER FLAMMABILITY LIMIT (LFL) UNITS (volume % to g/m³)



Example: Xylenes, MW = 106, LFL = 1.1%, then LFL in g/m³ = 50

Note: data applicable at 25°C and 760 mm Hg pressure

TABLE 8 MAXIMUM PLUME HAZARD HALF-WIDTHS (for xylene at 20°C)

Weather Condition D			Weather Condition F		
Q/U (g/m)	$(W/2)_{max}$ (m)		Q/U (g/m)	$(W/2)_{max}$ (m)	
30 000 000	3400	(99.5 km)*	2 500 000	1385	(97.4 km)*
25 000 000	3030		2 000 000	1175	
20 000 000	2640		1 500 000	985	
15 000 000	2210		1 000 000	700	
10 000 000	1720		750 000	565	
8 000 000	1500		500 000	420	
6 000 000	1255		400 000	350	
5 000 000	1120		300 000	295	
3 000 000	815		250 000	260	
2 500 000	730		200 000	225	
2 000 000	635		150 000	190	
1 500 000	540		100 000	145	
1 000 000	425	Q/U = 38 095 →	50 000	95	→ $(W/2)_{max}$ = 95 m
750 000	360		25 000	60	
500 000	285		20 000	50	
400 000	250		10 000	35	
300 000	210		5 000	25	
200 000	165		1 000	10	
150 000	140				
100 000	110				
50 000	75				
25 000	50				
10 000	32				
5 000	20				
1 000	10				

*Data are provided up to a maximum downwind hazard distance of 100 km.

Example: A spill releasing xylene vapour at the rate of $Q = 8.0 \times 10^4$ g/s under weather condition F and a wind speed U = 2.1 m/s means Q/U = 38 095 g/m which results in a maximum plume hazard half-width $(W/2)_{max}$ = 95 m.

Note: Above table is valid only for a xylene concentration of 10 x TLV•, or 4.35 g/m^3.

Use: Knowing the weather condition, Q and U, compute Q/U. Choose the closest Q/U value in the table and the corresponding $(W/2)_{max}$, the maximum plume hazard half-width, in metres. (For an intermediate value, interpolate Q/U and $(W/2)_{max}$ values.) Also refer to the example at the bottom of Table 8.

5.3.2.4 Figure 18: Plume travel time versus travel distance. Figure 18 presents plots of plume travel time (t) versus plume travel distance (X_t) as a function of different wind speeds (U). This is simply the graphical presentation of the relationship $X_t = Ut$ for a range of typical wind speeds.

Use: Knowing the time (t) since the spill occurred and the wind speed (U), the distance (X_t) can be determined, which indicates how far downwind the plume has travelled.

5.3.3 Sample Calculation. The sample calculation given below is intended to outline the steps required to estimate the downwind hazard zone which could result from a spill of liquid xylene. The user is cautioned to take note of the limitations in the calculation procedures described herein and in the Introduction Manual. The estimates provided here apply only for conditions given. It is recommended that the user employ known or observational estimates (i.e., of the spill radius) in a particular spill situation if possible.

Problem:

During the night, at about 2:00 a.m., 20 tonnes of xylene were spilled on a flat ground surface. It is now 2:05 a.m. The temperature is 20°C and the wind is from the NW at 7.5 km/h. Determine the extent of the vapour hazard zone.

Solution

Step 1: Quantity spilled is given, q = 20 tonnes

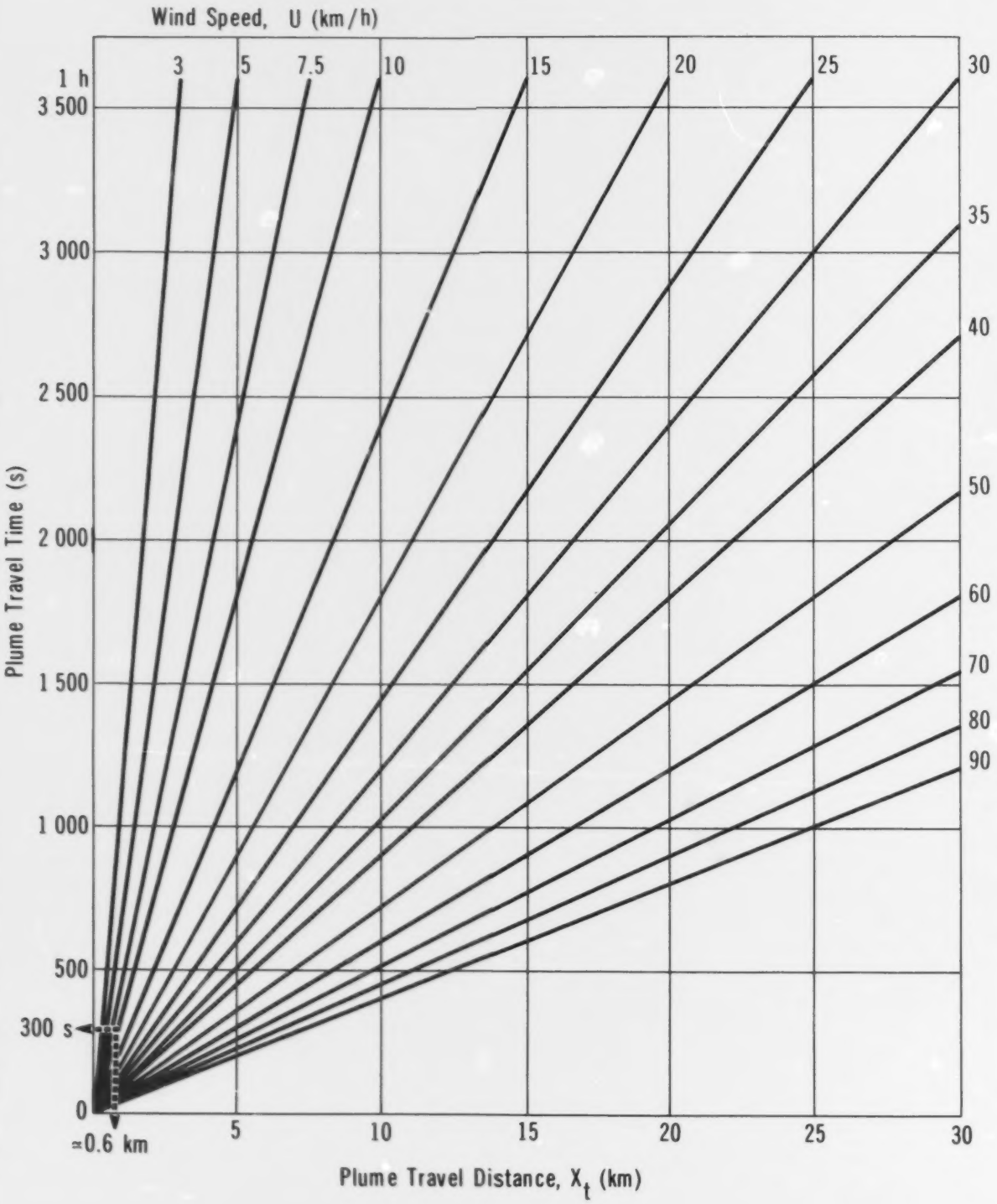
Step 2: Determine the pool radius (r) for a spill of 20 tonnes

- Use the observed (measured) pool radius if possible. If not, use the maximum radius from Figure 21, Section 5.4. Note that use of these data, which apply specifically to spills on water, will result in an exaggerated pool radius on land
- Radius (r) = 250 m ÷ 1000 = 0.25 km

FIGURE 18

XYLENES

PLUME TRAVEL TIME VS TRAVEL DISTANCE



Step 3: Calculate the vapour emission rate (Q) at T = 20°C

- From Figure 14, for r = 250 m and T = 20°C, $Q = 8.0 \times 10^4$ g/s

Step 4: Determine the wind speed (U) and direction (D)

- Use available weather information, preferably on-site observations
- Given:

  U = 7.5 km/h, then U = 7.5 ÷ 3.6 = 2.1 m/s

  D = NW or 315° (D = Direction from which wind is blowing)

Step 5: Determine the weather condition

- From Table 7, weather condition = F since U is less than 11 km/h and it is night

Step 6: Determine the hazard concentration limit (C)

- This is the lower of 10 times the TLV®, or the LFL, so for xylene

  $C = 4.35$ g/m^3 (TLV® = 0.435 g/m^3; LFL = 50 g/m^3)

Step 7: Compute CU/Q

- $$CU/Q = \frac{4.35 \times 2.1}{8.0 \times 10^4} = 1.14 \times 10^{-4} \text{ m}^{-2}$$

Step 8: Calculate the downwind distance (X_p) from the virtual point source

- From Figure 15, with $CU/Q = 1.4 \times 10^{-4}$ m^{-2} and weather condition F, $X_p \simeq 3.75$ km

Step 9: Calculate the hazard distance (X_a) downwind of the area source

- With $X_p = 3.75$ km and r = 0.25 km

  then $X_a = X_p - 10\ r = 3.75 \text{ km} - 10\ (0.25 \text{ km}) = 1.25$ km

Step 10: Calculate the plume hazard half-width $(W/2)_{max}$

- Use Table 8
- With $Q = 8.0 \times 10^4$ g/s and U = 2.1 m/s

  then $$Q/U = \frac{8.0 \times 10^4}{2.1} = 38\,095 \text{ g/m}$$

- Then for weather condition F, the closest Q/U value is 50 000 g/m which gives $(W/2)_{max} \approx 95$ m

Step 11: Determine the time since the spill

- $t = 5$ min x 60 = 300 s

Step 12: Calculate the distance travelled (X_t) by the vapour plume since the time of the accident

- Using Figure 18, with $t = 300$ s and $U = 7.5$ km/h, then $X_t = 0.6$ km (more accurately from $Ut = 2.1$ m/s x 300 s = 630 m = 0.63 km)

Step 13: Map the hazard zone

- This is done by drawing a rectangular area with dimensions of twice the maximum plume hazard half-width (95 m) by the maximum hazard distance downwind of the area source (1.25 km) along the direction of the wind, as shown in Figure 19
- If the wind is reported to be fluctuating by 20° aobut 315° (or from 315° $\pm$ 10°), the hazard zone is defined as shown in Figure 20
- Note that the plume has only travelled 0.63 km in the 5 minutes since the spill. At a wind speed of 7.5 km/h, there remain 5 minutes before the plume reaches the maximum downwind hazard distance of 1.25 km

5.4 Behaviour in Water

5.4.1 Introduction. The rate of spreading on water is based on the balance between forces tending to spread the liquid (gravity and surface tension) and those tending to resist spreading (inertial and viscous forces).

In addition to the natural spreading tendency, the spill slick will move in the same direction and at the same speed as the surface water. Surface water direction and speed are influenced by currents and wind forces. Factors considered in the spill nomograms are illustrated in the following chart:

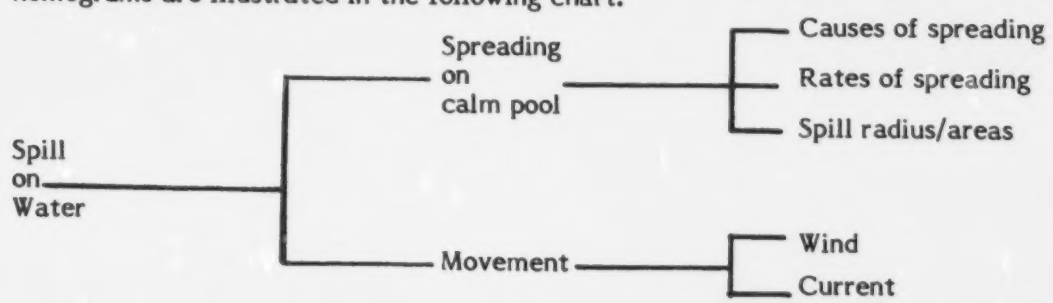


FIGURE 19

XYLENES

HAZARD AREA FOR STEADY WINDS, EXAMPLE PROBLEM

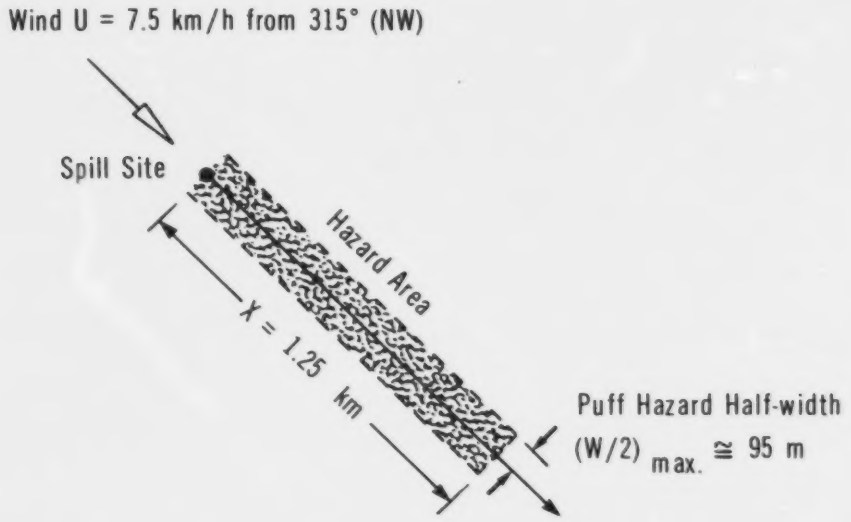
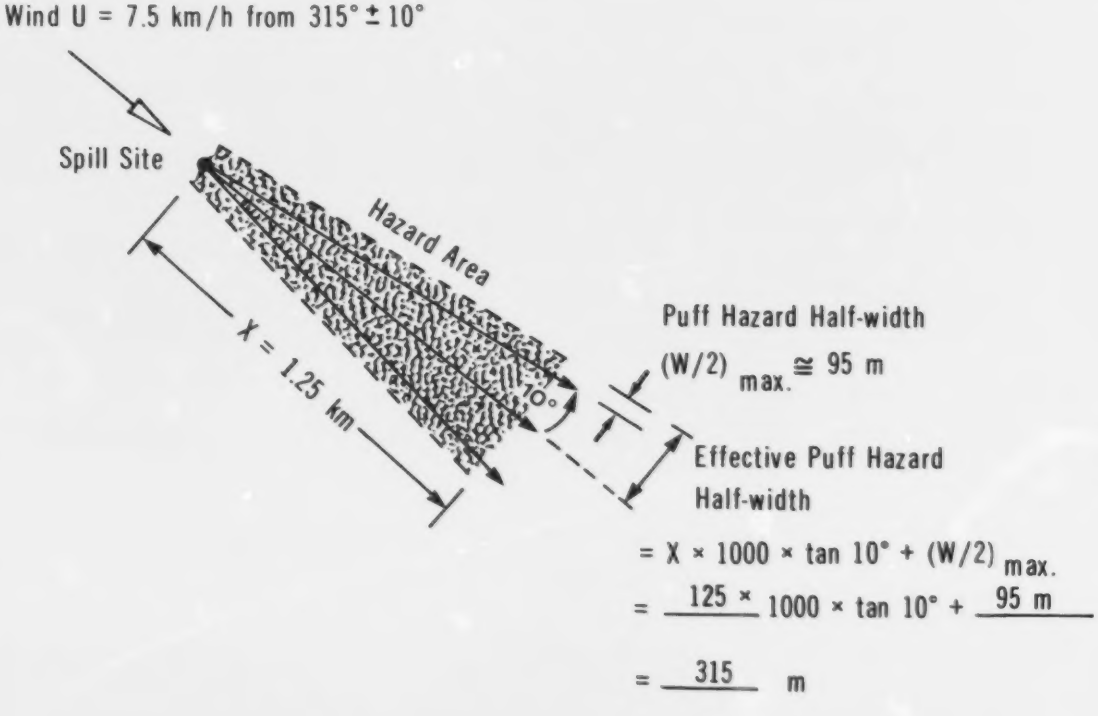


FIGURE 20

XYLENES

HAZARD AREA FOR UNSTEADY WINDS , EXAMPLE PROBLEM


Wind U = 7.5 km/h from 315° ± 10°
Spill Site
Hazard Area
X = 1.25 km
10°
Puff Hazard Half-width
(W/2) max. ≅ 95 m
Effective Puff Hazard
Half-width
= X × 1000 × tan 10° + (W/2) max.
= 125 × 1000 × tan 10° + 95 m
= 315 m

5.4.2 Nomograms. The following nomograms are presented to simplify calculations:

Figure 21: spill radius versus time (still water - unconfined) for various sizes of spills; maximum spill radius indicated

Figure 22: length of channel affected versus equivalent spill radius (still water - confined) for a number of stream widths

Figure 23: translation distance versus time for a range of surface water velocities

Figure 24: vectoral addition of surface current and wind

5.4.2.1 Figure 21: Spill radius versus time (still water - unconfined). Figure 21 provides a means of calculating the radius/area of an unconfined slick of xylene for a known mass of spill and at a defined time from the occurrence of the spill. The equations representing the spreading of the spill on water are presented in the Introduction Manual. A critique of the spreading model (Eisenberg 1975) suggests that the equations are valid for cases where the viscosity of the spilled liquid is greater than or equal to 0.2 times the viscosity of water ($U_L \geq 0.2\ U_w$).

For the purposes of the nomogram presented, the water/spill temperature has been taken at 20°C, representing a reasonable maximum for surface water bodies. This condition maximizes the spill size at any time of interest. If the indicated pool radius is larger than the theoretical maximum radius, use the theoretical maximum pool radius.

5.4.2.2 Figure 22: Length of channel affected versus equivalent spill radius (still water - confined). If the distance between the banks of the water body is less than the spill diameter, the slick will be confined. Using the effective radius of spill from Figure 21, the approximate length of channel affected by the spill can be computed from Figure 22, if the stream width is known.

5.4.2.3 Figure 23: Translation distance versus time (no wind). Figure 23 presents a simple relationship between velocity, time, and distance. The distance a spill will be translated in time by a flowing stream is directly proportional to the surface current.

5.4.2.4 Figure 24: Vectoral addition of surface current and wind. To take into account the effect of both wind and surface current, the spill slick is assumed to move with a velocity given by the vectoral addition of current velocity and 3 percent of the wind velocity (Raj 1974; Fingas 1979, 1980).

Figure 24 is designed to simplify vectoral addition of the current and velocity components. The horizontal velocity axis is scaled for wind velocity, in kilometres per hour. The surface current vector is added to the wind vector by determining its direction

FIGURE 21

XYLENES

SPILL RADIUS VS TIME
(still water - unconfined)

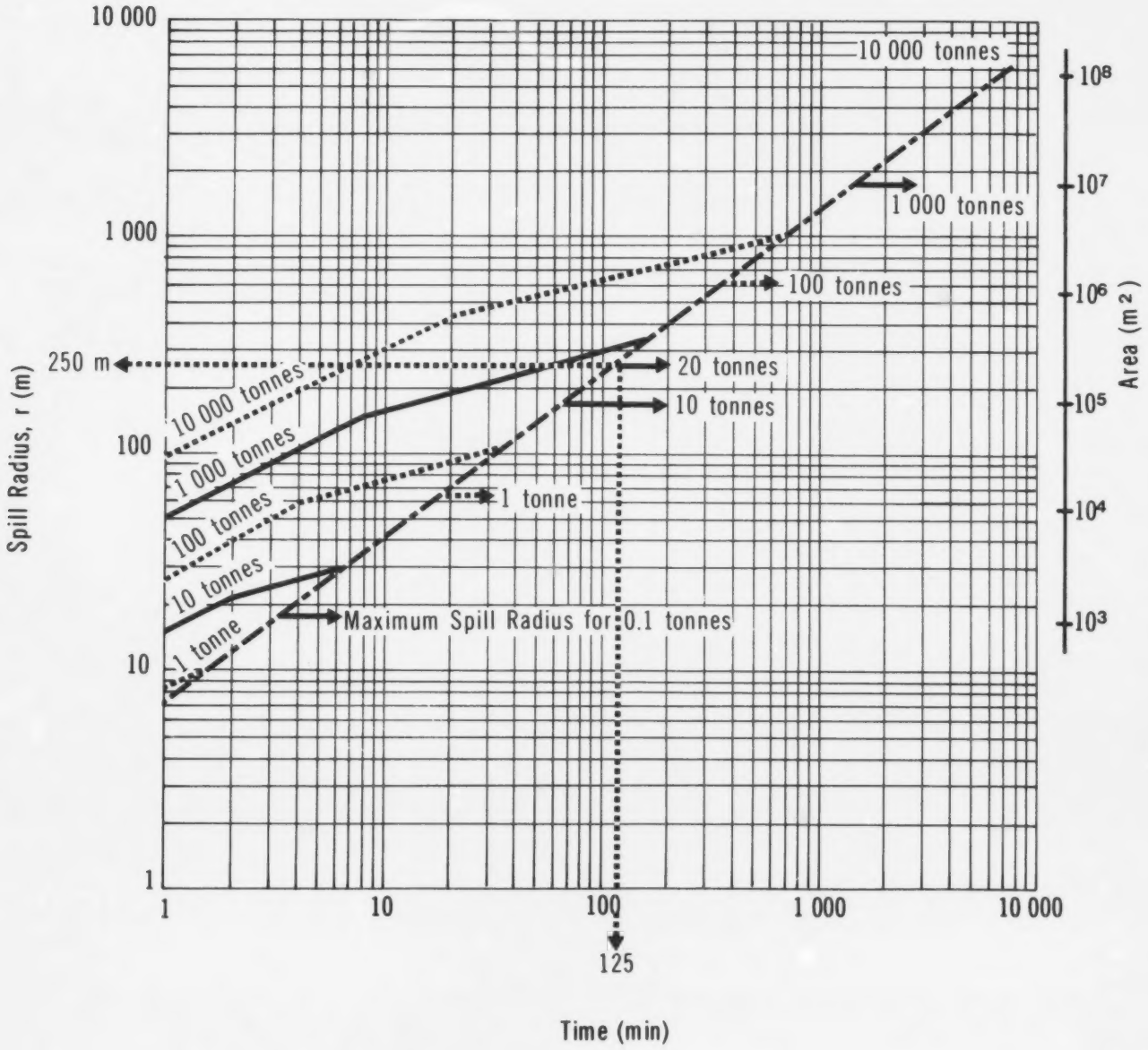


FIGURE 22

XYLENES

LENGTH OF CHANNEL AFFECTED VS SPILL RADIUS (still water - confined)

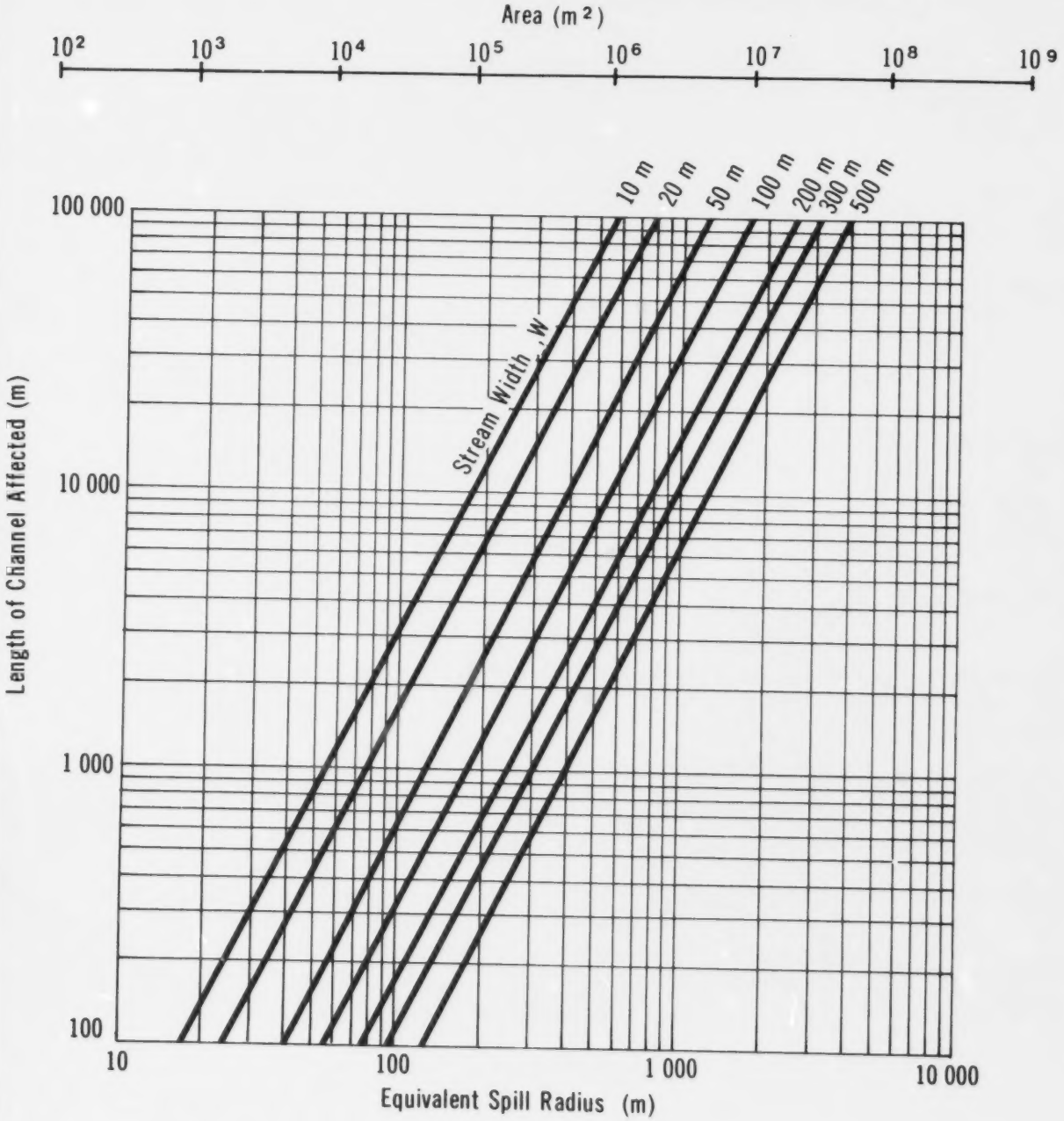


FIGURE 23

XYLENES

TRANSLATION DISTANCE (no wind)

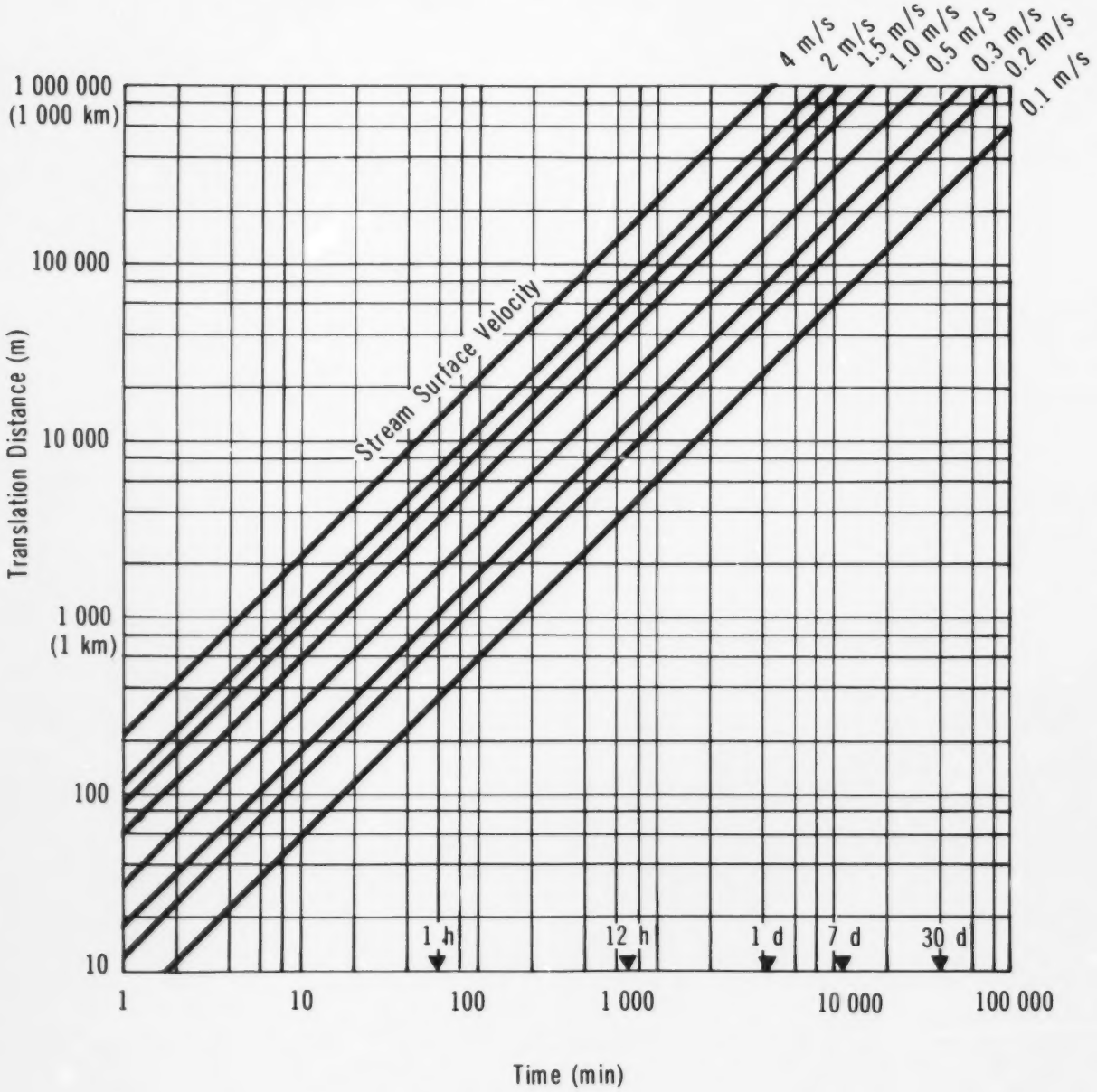
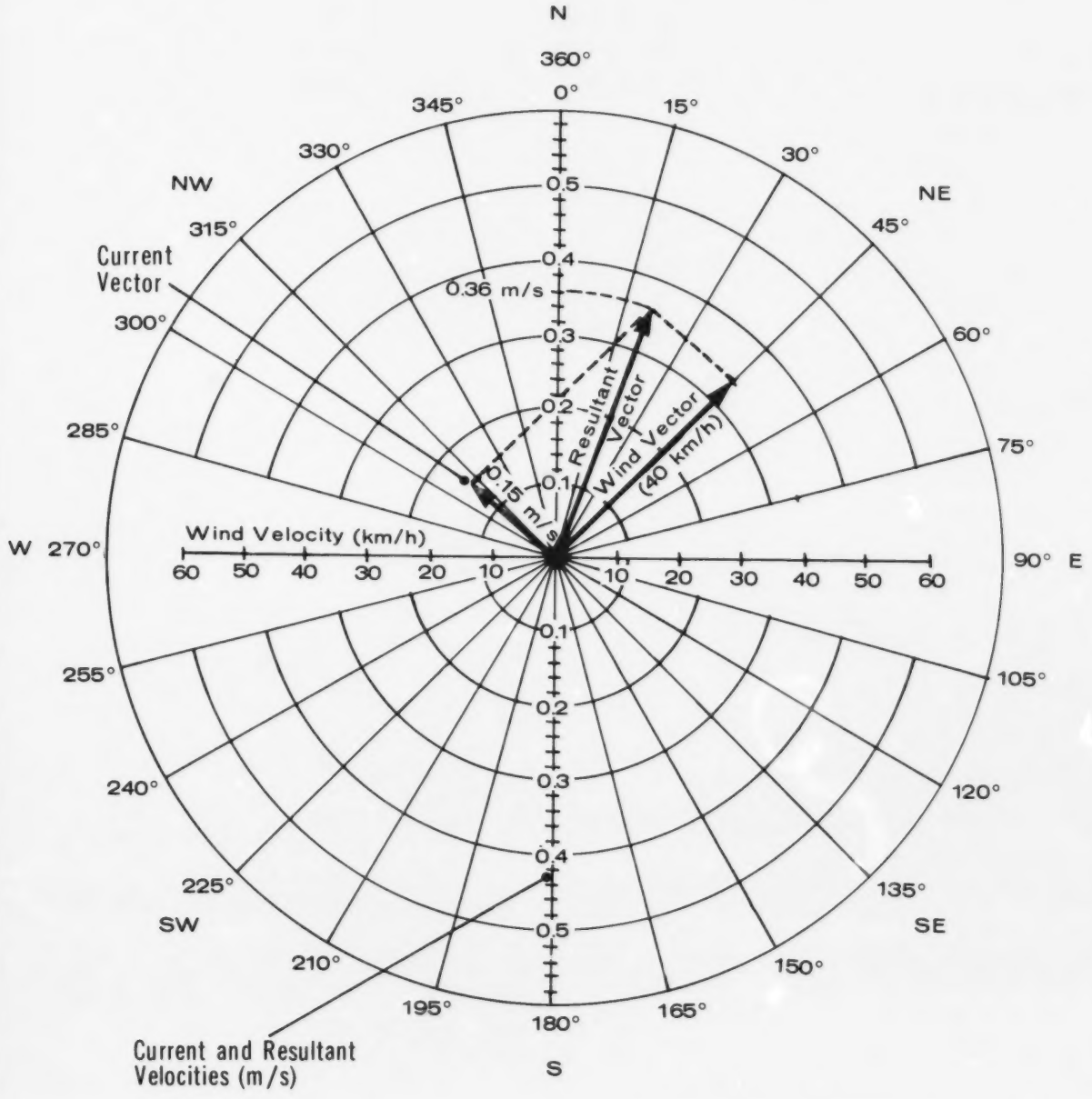


FIGURE 24

XYLENES

VECTORAL ADDITION OF SURFACE CURRENT AND WIND



relative to the wind direction. The length of the surface current vector is defined by the vertical surface current velocity scale, in m/s. The resultant vector describes the direction and velocity the spill slick will be moving due to wind and current effects. The length of the resultant vector represents the spill translation velocity (m/s) when measured against the vertical scale.

The nomogram does not account for deformation of the slick shape when influenced by wind and/or surface currents, or for any losses which occur by evaporation or any other means.

5.4.3 Sample Calculations

i) Problem A

A 20 tonne spill of xylene has occurred on a large lake. The wind is calm. Determine the size of the spill after 20 minutes, together with the maximum spill size and approximate time of occurrence.

Solution to Problem A

- Use Figure 21
- With t = 20 min and for a spill mass of 20 tonnes, the spill radius (r) is estimated at about 60 m by interpolation
- Similarly, the maximum spill radius (r_{max}) of about 250 m will occur in approximately 125 min (2 h)

ii) Problem B

The slick in Problem A is confined to a calm channel, approximately 50 m in width. What is the maximum length of channel affected by this spill?

Solution to Problem B

- Figure 21 (or Solution to Problem A) gives r_{max} = 250 m for a 20 tonne spill
- Using Figure 22, with r_{max} = 250 m and a stream width of 50 m, the maximum length of channel affected under still conditions is about 4000 m (4 km)

iii) Problem C

The 20 tonne spill in Problem A is being affected by a wind velocity of 40 km/h from the southwest and a surface current of 0.15 m/s at 90° from the wind direction (i.e., flow is northwest). What is the resultant direction and speed of the slick and the distance the slick has moved when it reaches its maximum size?

Solution to Problem C

Step 1: Define the wind vector

- Use Figure 24
- Determine the length of the wind vector for 40 km/h against the horizontal wind velocity scale
- Draw the wind vector at the appropriate length and in a northeasterly direction starting at the origin

Step 2: Define the surface current vector

- Determine length of the surface current vector of 0.15 m/s against the vertical axis on Figure 24
- Draw the surface current vector at the appropriate length and in a northwesterly direction, starting from the head of the wind vector

Step 3: Define the resultant vector

- Draw the resultant vector from the origin to the head of the current vector
- Direction of translation as given by the resultant vector is about 20° east of North
- Define the translation velocity by measuring the length of the resultant vector against the vertical scale. Spill translation velocity is estimated at 0.36 m/s

Step 4: Determine the distance travelled when the spill reaches its maximum radius

- From Figure 21 (or Problem A), r_{max} = 250 m at t = 125 min (7500 s)
- Distance travelled = 7500 s x 0.36 m/s = 2700 m, by the time the spill reaches its maximum radius

5.5 Subsurface Behaviour: Penetration into Soil

5.5.1 Introduction. The general principles of contaminant transport in soil and their application to this work are described in the Introduction Manual. Specific items related to xylene and the development of nomograms for it are presented here.

Xylene has a low solubility in water. Consequently, when spilled onto soil, its infiltration and transport downward through the soil involve multi-phase phenomena. The phases of concern are liquid xylene, water, soil, and gas or vapours.

Unfortunately, sufficient data do not exist to permit a detailed assessment of contaminant transport in a specific circumstance. A few extensive field investigations have been carried out, especially involving spills of oil, gasoline and PCBs. But, for xylene, very limited information exists. Consequently, it is necessary to simplify the soil and groundwater conditions and to express contaminant behaviour through analogy to other more extensively studied materials. A pattern for the downward movement of immiscible fluids such as xylene in soil has been prepared by comparison to oil spilled onto soil surfaces (Blokker 1971; Freeze and Cherry 1979).

It is assumed that when the spill occurs, the soil contains water only up to its field capacity and that this condition prevails down to the groundwater table. The spilled xylene fills the pores at the soil surface and begins to penetrate downward. It is assumed that the liquid moves downward through the soil as a saturated slug, but leaving behind a constant residual amount (S_o) within the soil pores. Downward transport will continue until the volume of xylene spilled per unit area (B_o) equals the amount retained in the soil as S_o. Some lateral spreading may occur due to capillary action. If B_o is greater than the volume that can be retained as S_o above the groundwater table, the excess xylene will spread as a pancake within the saturated groundwater capillary fringe. The resultant contaminated zone consisting of a "vertical" column and "horizontal" pancakes of soil containing the residual amount of xylene, S_o, is shown schematically in Figure 25.

5.5.2 Equations Describing Xylene Movement into Soil. The equations and assumptions used to describe contaminant movement downward through the unsaturated soil zone toward the groundwater table have been described in the Introduction Manual. Transport velocities have been based on Darcy's Law assuming saturated piston flow.

5.5.3 Saturated Hydraulic Conductivity of Xylene in Soil. The saturated hydraulic conductivity (K_o), in m/s, is given by:

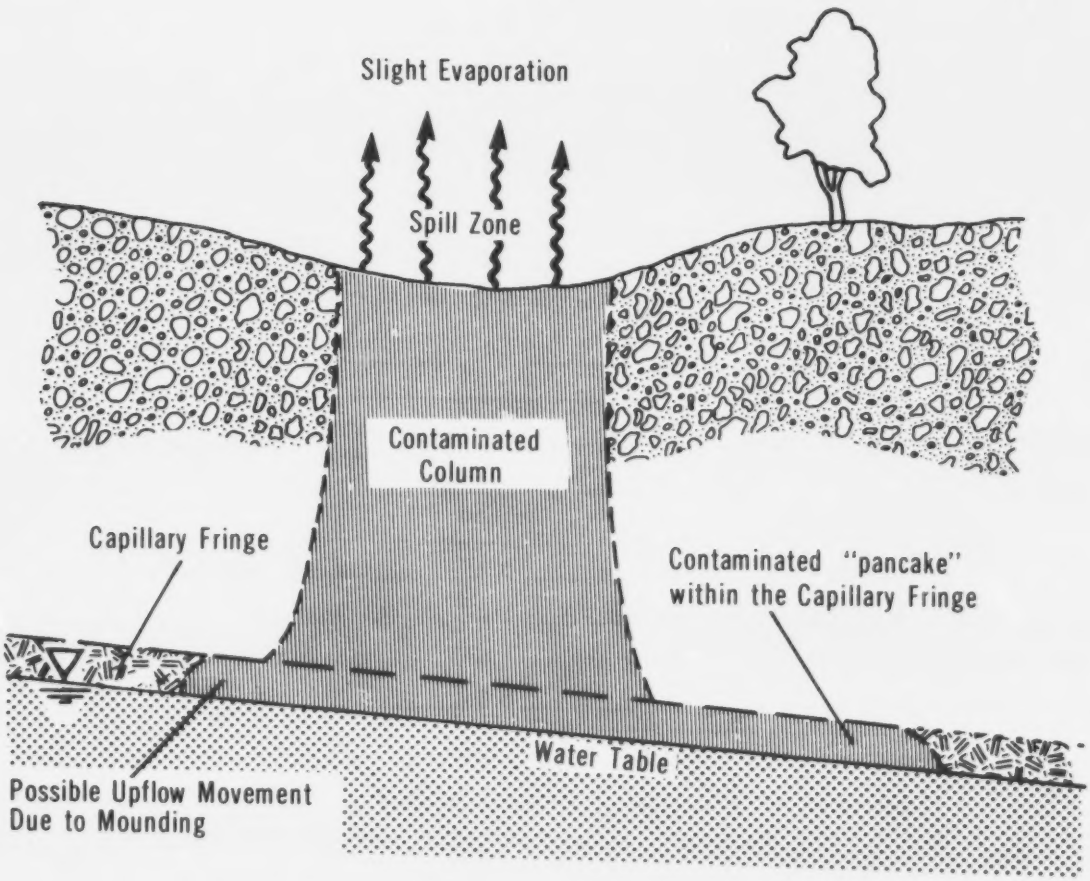
$$K_o = \frac{(\rho g)k}{\mu}$$

where:
- k = intrinsic permeability of the soil (m^2)
- ρ = mass density of the fluid (kg/m^3)
- μ = absolute viscosity of the fluid ($Pa \cdot s$)
- g = acceleration due to gravity = 9.81 m/s^2

FIGURE 25

XYLENES

SCHEMATIC SOIL TRANSPORT



Soil: Coarse Sand

–Porosity (n) = 0.35

–Intrinsic Permeability (k) = 10^{-9} m^2

–Field Capacity (θ_{fc}) = 0.075

The appropriate properties of xylene are given in the chart below:

Property	Xylene	
	20°C	4°C
Mass density (ρ), kg/m^3	880	885
Absolute viscosity (μ), Pa•s	0.8×10^{-3}	0.9×10^{-3}
Saturated hydraulic conductivity (K_o), m/s	$(1.1 \times 10^{7})k$	$(1.0 \times 10^{7})k$

5.5.4 Soils. The Introduction Manual describes the three soils selected for this work. Their relevant properties are:

Property	Soil Type		
	Coarse Sand	Silty Sand	Clay Till
Porosity (n), m^3/m^3	0.35	0.45	0.55
Intrinsic permeability (k), m^2	10^{-9}	10^{-12}	10^{-15}
Field capacity (θ_{fc}), m^3/m^3	0.075	0.3	0.45
Residual fraction (S_o), m^3/m^3	0.05	0.1	0.2

5.5.5 Penetration Nomograms. Nomograms for the penetration of xylene into the unsaturated zone above the groundwater table were prepared for each soil. The nomograms show the total depth of penetration (B) versus penetration time (t_p) for various volumes spilled per unit area of soil (B_o). Temperatures of 4°C and 20°C were used. Calculations were based on the equations developed in the Introduction Manual. A flowchart for use of the nomograms is shown in Figure 26. The nomograms are presented in Figures 27, 28 and 29.

5.5.6 Sample Calculation. A 20 tonne spill of xylene has occurred on coarse sandy soil. The temperature is 20°C; the spill radius is approximately 8.6 m. Calculate the depth and time of penetration.

FIGURE 26

XYLENES

FLOWCHART FOR NOMOGRAM USE

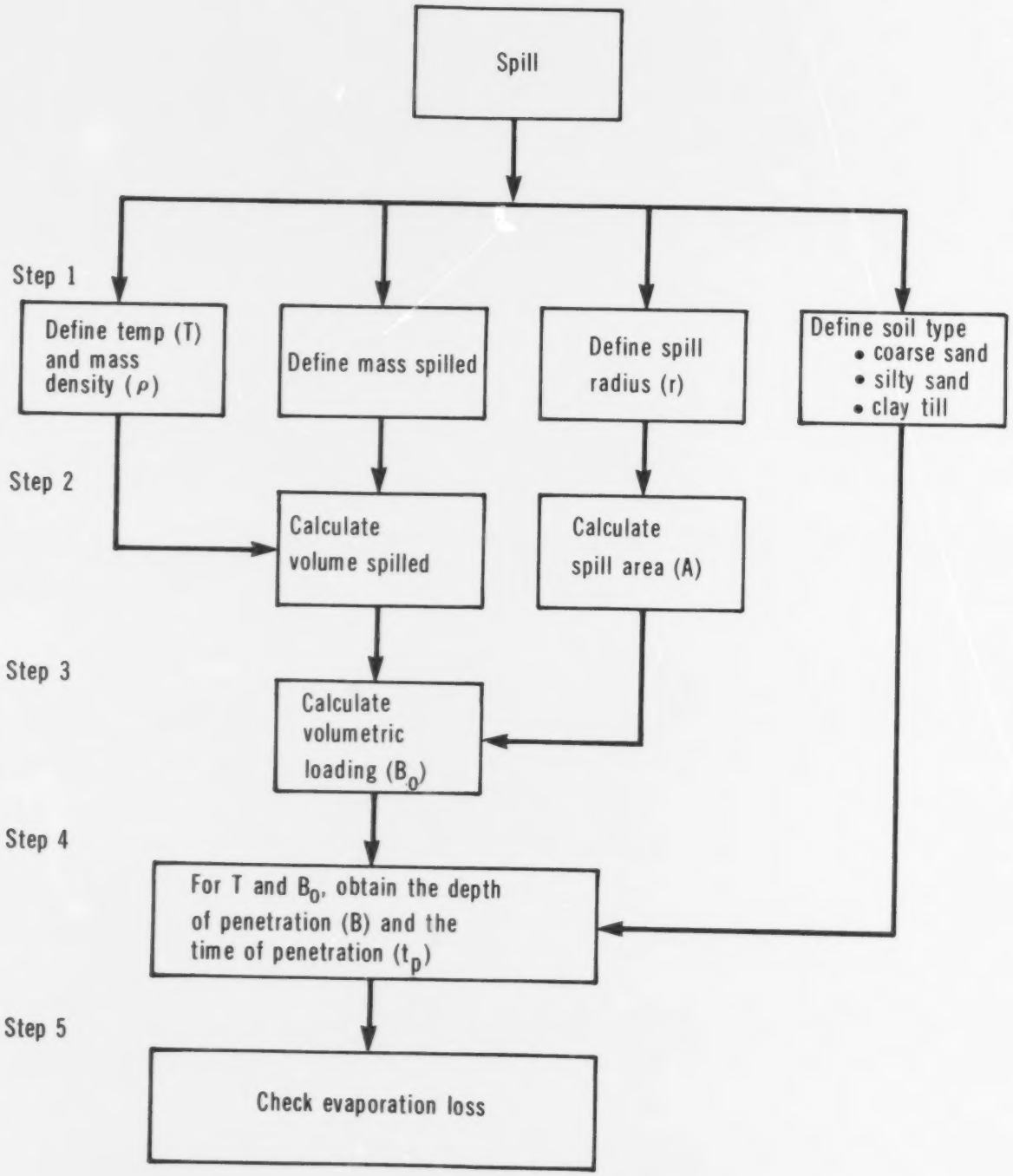


FIGURE 27

XYLENE

PENETRATION IN COARSE SAND

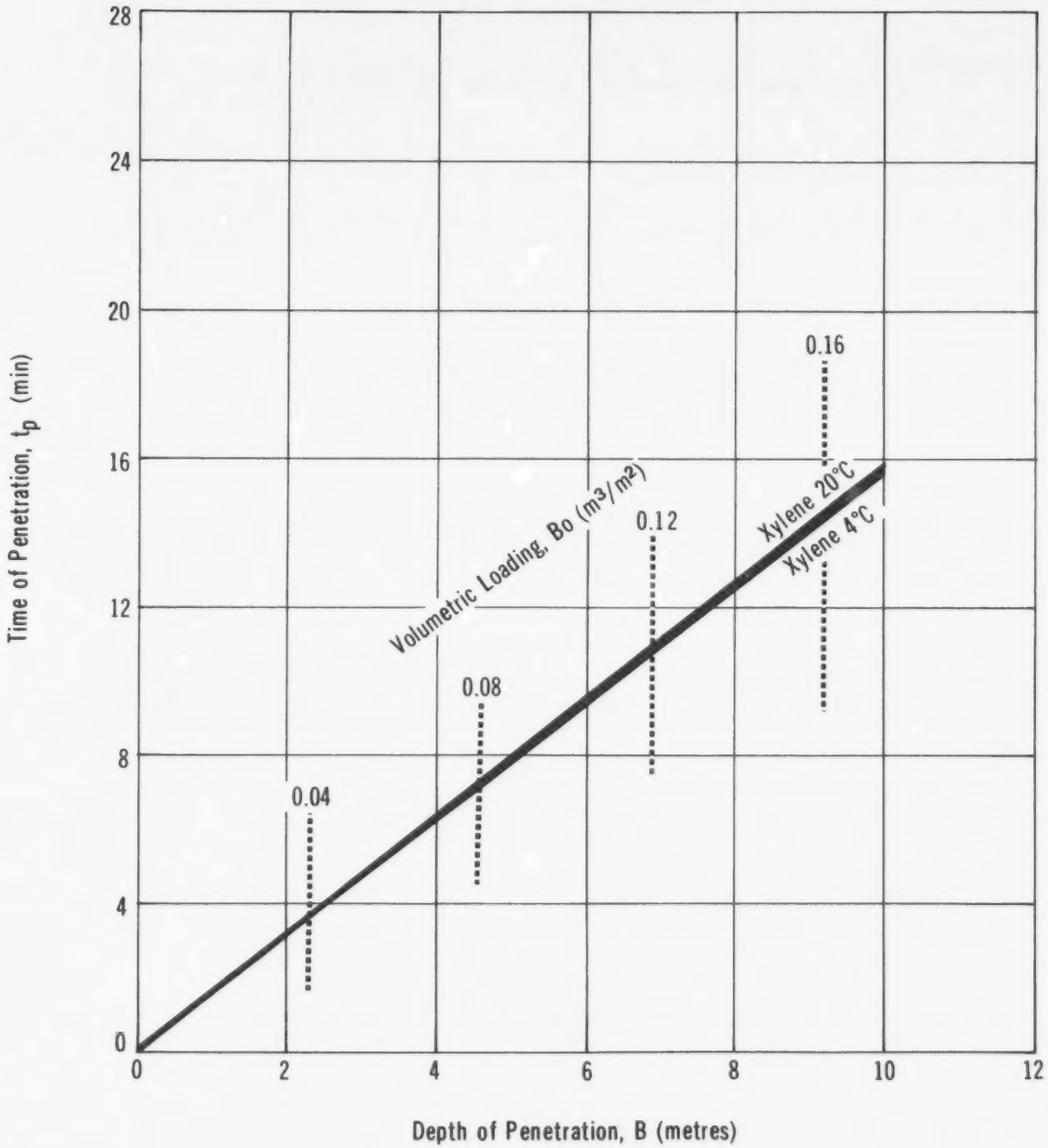


FIGURE 28

XYLENE

PENETRATION IN SILTY SAND

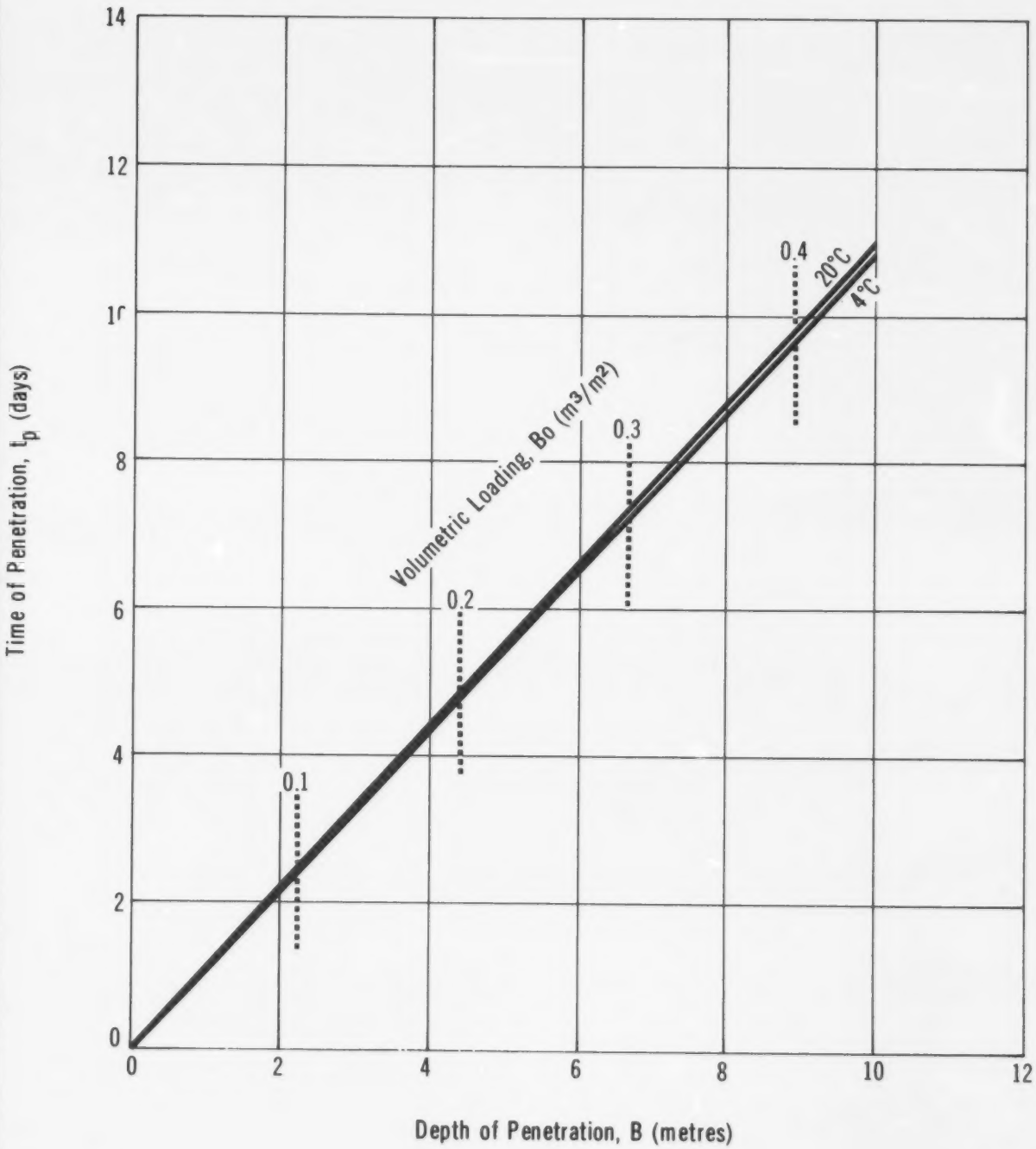
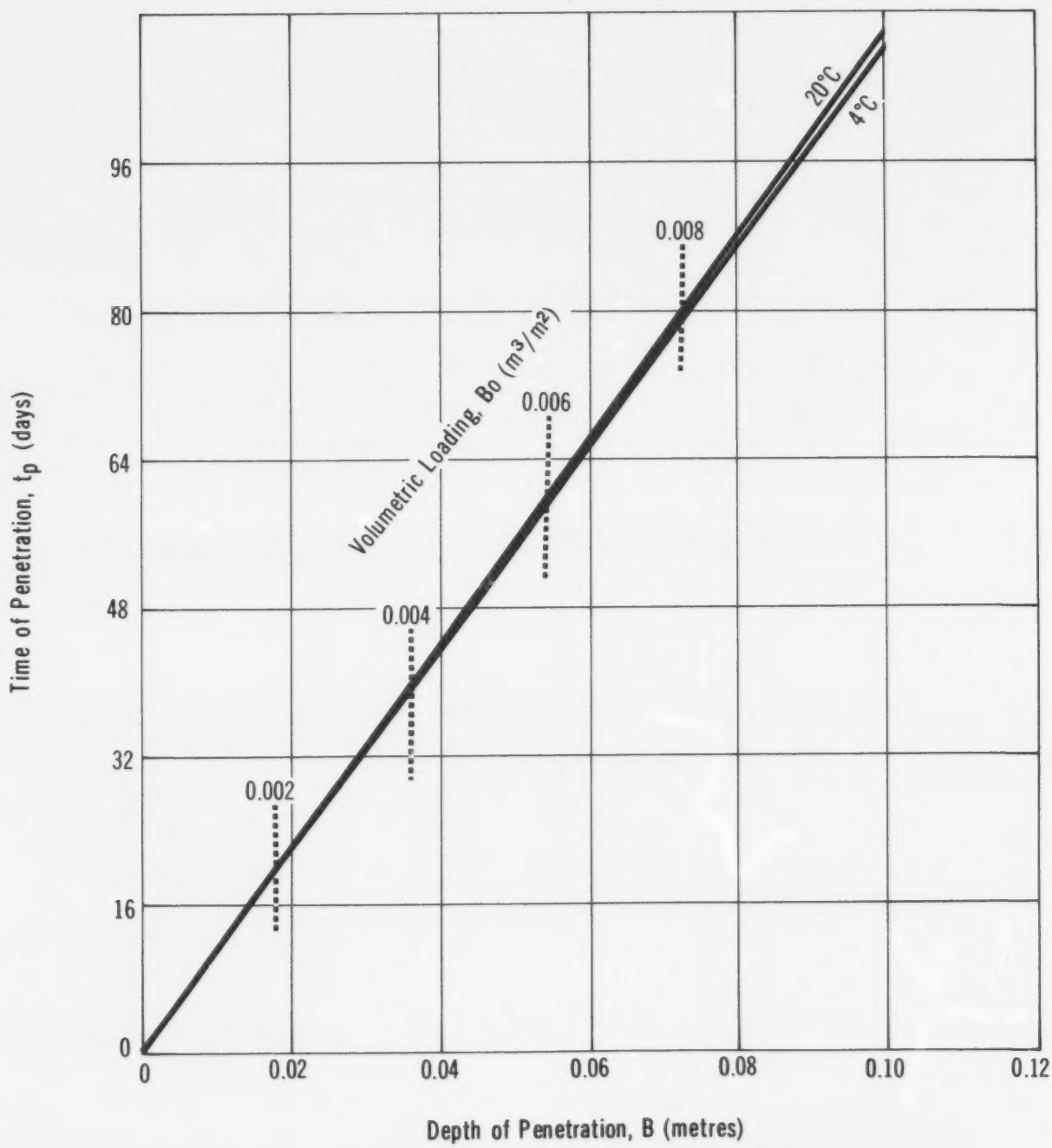


FIGURE 29

XYLENE

PENETRATION IN CLAY TILL



Solution

Step 1: Define parameters

- Mass spilled = 20 000 kg (20 tonnes)
- T = 20°C
- Mass density (ρ) = 880 kg/m^3
- r = 8.6 m

Step 2: Calculate the volume and area of spill

- $V = \frac{M}{\rho} = \frac{2 \times 10^4 \text{ kg}}{880 \text{ kg/m}^3} = 22.7 \text{ m}^3$
- $A = \pi r^2 = 232 \text{ m}^2$

Step 3: Calculate the volumetric loading B_o

- $B_o = \frac{V}{A} = \frac{22.7}{232} = 0.1 \text{ m}^3/\text{m}^2$

Step 4: Estimate the depth of penetration (B) and the time of penetration (t_p), using Figure 27

- For coarse sand, $B_o = 0.1 \text{ m}^3/\text{m}^2$
- B = 5.8 m, t_p = 8.9 min

6 ENVIRONMENTAL DATA

6.1 Suggested or Regulated Limits

6.1.1 Water. Canada does not specifically regulate xylenes in drinking water. In Ontario's Water Management Goals (1978), xylene tolerance limits are not defined, but it is noted that it is "very toxic" to fish. In the United States, a limit of 0.05 mg/L is recommended based on organoleptic properties (WQCDB-1 1970).

6.1.2 Air. In Ontario, total xylenes concentration in air is limited to 2300 $\mu g/m^3$ (2.3 mg/m^3) (Ontario E.P. Act 1971). Several eastern European countries have a 200 $\mu g/m^3$ (0.2 mg/m^3) limit for o-xylene (Verschueren 1984).

6.2 Aquatic Toxicity

6.2.1 U.S. Toxicity Rating. Xylene has been assigned a TL_m96 of 10 to 100 ppm.

6.2.2 Measured Toxicities.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Toxicity Tests					
m-Xylene					
5	24	Bluegill	illness	Lake Huron water	WQC 1963
5	24	Rainbow trout	no effect	Lake Huron water	WQC 1963
16	24	Goldfish	LC_{50}	20°C	Bridié 1979
38	336 (14 d)	Guppy	LC_{50}	-	Verschueren 1984
9.2	96	Bass (*Morone saxatilis*)	LC_{50}	-	Verschueren 1984
o-Xylene					
13	24	Goldfish	LC_{50}	20°C	Bridié 1979
13.5	96	Rainbow trout	LC_{50}	-	Verschueren 1984
16.9	96	Goldfish	LC_{50}	-	Verschueren 1984

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
46	1	Fathead minnow	LC_{50}	static, 18-22°C, Lake Superior water	Verschueren 1984
42	24-96	Fathead minnow	LC_{50}	static, 18-22°C, Lake Superior water	Verschueren 1984
11	96	Bass	LC_{50}	static, 18-22°C, Lake Superior water	Verschueren 1984
p-Xylene					
27-29	24-96	Fathead minnow	TL_m	hard and soft water	Verschueren 1984
21-24	24-96	Bluegill	TL_m	soft water	Verschueren 1984
18	24	Goldfish	LC_{50}		Bridié 1974
35	168	Guppy	LC_{50}		Verschueren 1984
2	96	Bass	LC_{50}		Verschueren 1984
m-, o- and p-Xylene					
21	96	Fathead minnow	TL_m	static, temperature controlled	Pickering 1966
22	96	Bluegill	TL_m	static, temperature controlled	Pickering 1966
24	96	Goldfish	TL_m	static, temperature controlled	Pickering 1966
39	96	Guppy	TL_m	static, temperature controlled	Pickering 1966
24	24-48	Fathead minnow	LC_{50}	static	Buikema 1980

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Unspecified xylenes					
8.2	96	Rainbow trout	LC_{50}	12°C	Johnson 1980
13.5	76	Bluegill	LC_{50}	12°C	Johnson 1980
20	48	Zebrafish	LC_{50}	flow-through, 20°C, pH 8.0	Sloof 1979
30.6	24	Goldfish	LC_{50}	flow-through, 17-19°C, pH 7.0 HD 80	Buikema 1980
25.1	48	Goldfish	LC_{50}	flow-through, 17-19°C, pH 7.0 HD 80	Buikema 1980
20.7	72	Goldfish	LC_{50}	flow-through, 17-19°C, pH 7.0 HD 80	Buikema 1980
16.9	96	Goldfish	LC_{50}	flow-through, 17-19°C, pH 7.0 HD 80	Buikema 1980
14.6	720	Goldfish	LC_{50}	continuous flow	Buikema 1980
Microorganisms					
o-Xylene					
55	24	Algae	50 percent reduction in cell numbers	20°C	Kauss 1975

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
171	immediate	Algae (*Chlorella vulgaris*)	toxic concentration	20°C	Kauss 1975
o-, *m*- and *p*-Xylene					
230 (3.77 mmole/L)	24	Ciliate (*Tetrahymena pyriformis*)	LC_{100}	-	Verschueren 1984
10 000	immediate	Phytoplamkton (*Skeletonema costatum* and *Cricosphaera carterae*)	inhibition of growth	-	Buikema 1980
100 000	immediate	Phytoplankton (*Dunaliella tertiolecta*)	inhibition of growth	-	Buikema 1980
Freshwater Invertebrates					
o-Xylene					
100-10 000	24	*Daphnia magna*	TL_m	-	Verschueren 1984
13.9	24	Mosquito (*Aedes aegypti*)	LC_{50}	-	Buikema 1980
Saltwater Fish					
o-Xylene					
10-100	24	Coho salmon (fry)	LC_{50}	static	Buikema 1980
100	24	Coho salmon (fry)	LC_{100}	static	Verschueren 1984
Saltwater Invertebrates					
m-Xylene					
4.8	24	Bay shrimp (*Cargo franciscorum*)	LC_{50}	static	Buikema 1980
3.7	96	Bay shrimp	LC_{50}	static	Buikema 1980

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
33	48	Crab (*Cancer magister*)	LC_{50}	continuous flow	Buikema 1980
12	96	Crab	LC_{50}	continuous flow	Buikema 1980
o-Xylene					
38	48	Crab (*Cancer magister*)	LC_{50}	continuous flow	Buikema 1980
6	96	Crab (*Cancer magister*)	LC_{50}	continuous flow	Buikema 1980
5.3	24	Bay shrimp (*Crago franciscorum*)	LC_{50}	static	Buikema 1980
1.3	96	Bay shrimp (*Crago franciscorum*)	LC_{50}	static	Buikema 1980
0.17	48	*Crassostrea gigas* larvae	LC_{50}	static	Buikema 1980
p-Xylene					
2	24	Shrimp (*Crago franciscorum*)	LC_{50}	static	Buikema 1980
2	96	Shrimp (*Crago franciscorum*)	LC_{50}	static	Buikema 1980
0.58	48	*Crassostrea gigas* larvae	LC_{50}	static	Buikema 1980
Unspecified xylenes					
7.4	96	Shrimp (*Palaemonetes pugio*)	LC_{50}	static	Buikema 1980
139	24	Crab (*Scylla serrata*)	LC_{50}	27-29°C, pH 7.6 to 8.0, Salinity 30°/$_{oo}$	Kulkarni 1983
131	48	Crab (*Scylla serrata*)	LC_{50}	27-29°C, pH 7.6 to 8.0, Salinity 30°/$_{oo}$	Kulkarni 1983

Conc. (mg/L)	Time (hours)	Species	Results	Water Conditions	Reference
114	72	Crab (*Scylla serrata*)	LC_{50}	27-29°C, pH 7.6 to 8.0, Salinity 30°/$_{oo}$	Kulkarni 1983
94	96	Crab (*Scylla serrata*)	LC_{50}	27-29°C, pH 7.6 to 8.0, Salinity 30°/$_{oo}$	Kulkarni 1983

6.3 Animal Toxicity

Xylenes have an acute oral toxicity of 2500 to 5000 mg/kg and an inhalation toxicity of 3000 to 8000 ppm (Miller 1976). One experiment was conducted on pigs fed a diet of fish meal for 55 days. Groups were fed 0.17 and 1.17 percent xylenes in the meal and effects were noted. The xylenes had no effect on weight gain but the normal albumin-globulin ratio was depressed. Pigs fed the 1.17 percent level were unsuitable for human consumption when slaughtered; however, if removed from the xylene diet 2 days before slaughter, they were considered suitable (Miller 1976).

6.4 Other Land and Air Toxicity

The threshold for harm to common crops is 800-2400 ppm (DPIMR 1981). In one study, 4.9 ppm (2.4×10^{-4} Mole/L) for 1 hour was lethal to young barley plants (Miller 1976). Chinaberry, maple and elm suffered severe damage when roots were treated with 500-1000 ppm xylene to control root rot (Miller 1976). Signs of plant toxicity include loss of turgor (rigidity), darkening of leaf tips, and bleaching of chlorophyll (Miller 1976). The roots of some plant species are stimulated by xylene concentrations of 0.01 to 0.1 ppm in water. This is true for barley and tomato but much less so for carrot, celery and parsley. The germination of some seeds (including beans, oats, lettuce and radishes) is retarded by 6 to 30 days by these levels of xylene in water. Xylenes have been used for aquatic weed control and will eliminate *Elodea canadensis* and *Potamogeton nodosus* at 100 ppm in water (Miller 1976).

Xylenes are toxic to insects at relatively low levels. The LC_{50} in air for the grain weavil (*Calandra granaria*) is 31 mg/L for *o*-xylene and 48 mg/L for *p*-xylene. A dose of 0.002 mL per insect is toxic to the housefly (*Musca domestica*) (Miller 1976).

6.5 Aquatic Studies

Rainbow trout were exposed to xylenes to test their avoidance reaction. No avoidance was observed at 0.001 and 0.01 mg/L; however, 79 percent of the fish were in the untreated water after 1 hour with 0.1 mg/L xylene (Folmar 1976).

Weber and co-workers conducted a series of experiments to determine the avoidance behaviour of coho salmon to petroleum hydrocarbon mixtures including xylenes as a component. Mature salmon migrating upstream during a peak run showed no avoidance behaviour at hydrocarbon mixtures of 3.2 mg/L in the water. Previous laboratory tests had shown that the AL_{50} (avoidance level for 50 percent of the test population) was 1.9 mg/L for coho smolt and 3.7 mg/L for presmolt coho salmon (Weber 1981). In another study, the lowest avoidance concentration for the mayfly nymph (*Ephemerella walkeri*) was 10 mg/L (Verschueren 1984).

The tainting (due to offensive odour) of fish is at a muscle tissue level of 0.02 ppm xylene (Buikema 1980).

Sloof (1979) developed an electrode system to detect respiratory frequency and set 2 mg/L (in 24 hours) as the level at which rainbow trout showed respiratory stress.

6.6 Degradation

	BOD (w/w)	% Theo.	Days	Seed	Reference
m-xylene					
		3.66	8	Aniline-acclimated activated sludge	Ryerman 1966
o-xylene					
		2.5	8	Aniline-acclimated activated sludge	Ryerman 1966
	0.64	1	5		Verschueren 1984
p-xylene					
		35.8	8	Aniline-acclimated activated sludge	Ryerman 1966
	0	1	5		Verschueren 1984
o-, *m*- and *p*-xylene					
		0	5	Sewage seed	Henkelekian 1955

Small amounts of xylenes (0.1 percent) seriously retard sewage digestion (OHM-TADS 1981). Microbial oxidation of *p*- and *m*-xylene by *Pseudomonas putida* results in cis-dihydrodiols. Oxidation by *Pseudomonas* P_{xy} and *Pseudomonas* P_{xy-4} was also noted. *m*-Xylene is transformed to *m*-tolualdehyde and *p*-xylene to *p*-tolualdehyde. *Pseudomonas* P_{xy-52} transforms *m*-xylene to 3-methyl catechol and 3-methyl salicyclic acid. A strain of *Nocardia* oxidizes *p*-xylene to a-dimethyl niconic acid (Buikema 1980).

6.7 Ambient Levels and Sources

Xylenes are present in urban environments at levels of 10 to 100 $\mu g/m^3$. Because of automobile emissions, these levels can rise to 200 $\mu g/m^3$ during rush hours. In one study, the level of *m*-xylene averaged 60 $\mu g/m^3$ and that of *p*-xylene averaged 30 $\mu g/m^3$ during rush hours (Hasanen 1981). The mean emissions of 31 cars tested in one study was 220 mg/km of *m*-xylene and 95 mg/km of *o*-xylene. The fuel used had 6.3 percent (w/w) *m*-xylene and 2.3 percent *o*-xylene (Hasanen 1981). A study done in Los Angeles in 1974 indicated that, of the percentage of total emissions per source, 9.1 and 3.4 percent (*m*- and *p*-, and *o*-xylenes, respectively) were emitted from automobile exhaust. Of the total emission from gasoline spills, 9.9 and 3.6 percent (*m*- and *p*-, and *o*-xylene, respectively) were xylenes. Similarly, of the total emissions of gasoline vapours, 2.2 percent was *m*- and *p*-xylene and 0.4 percent was *o*-xylene (NRC 1981).

Xylenes are a large constituent of gasoline. One sample tested had 6.7 percent *p*- and *m*-xylene and 2.86 percent *o*-xylene (NRC 1981). The xylene the content of samples of crude oil (Ullmann 1983) is shown below:

Xylene isomer	Crude Oil (%)	
	Arabian Light	Libyan
o-	1.0	2.4
m-	1.9	1.1
p-	2.1	0.9

6.8 Long-term Fate and Effects

Xylenes are estimated to have a half-life in water, at a depth of 1 m, of 5.6 hours (Verschueren 1984; MacKay 1973). This short half-life is due to evaporation; however, the biodegradation of remaining amounts is very slow. The half-life in soil is estimated to be 1-6 months (Miller 1976). In one study, the accumulation by marine eels

was several times (21.4, ortho; 23.6, meta) that of the ambient levels; however, there is no evidence that xylenes are bioconcentrated between trophic levels. Xylenes appear to be depurated after exposure (Miller 1976).

7 HUMAN HEALTH

Xylenes have received considerable attention in recent health effects literature. Because xylenes occur commercially as mixtures containing ortho, meta and para forms, most references, unless otherwise specified, refer to the mixture (Doc. TLV 1981). Mixtures are composed principally of the meta form of xylene, often with ethylbenzene present (Doc. TLV 1981). Xylenes, in cases of acute exposure, show predominant toxic effects on the central nervous system. Irritant effects on mucous membranes have been reported, particularly upon direct contact with xylenes.

Mixed xylenes have been selected for mutagenicity and teratogenicity testing by the U.S. Environmental Protection Agency under the Toxic Substances Control Act (TSCA). Under a joint Occupational Safety and Health Administration, U.S. Environmental Protection Agency and National Cancer Institute request, mixed xylenes were reported to be selected for testing at the National Cancer Institute in 1980 (USDHEW 1980). Mixed xylenes have not been found to be mutagenic nor designated as being teratogenic, although skeletal anomalies were found in offspring of exposed pregnant rats. No significant chromosome aberrations were found in rat bone marrow cells exposed to xylene at concentrations ranging from 0.044 to 0.441 mL/kg body weight.

Published work on xylene toxicology has been reviewed recently and xylenes have been reported in the U.S. Environmental Protection Agency TSCA Inventory.

The toxicological data summarized here have been extracted from reliable standard reference sources and are representative of information in the literature. It should be noted that some of the data are for chronic (long-term), low-level exposures and may not be directly applicable to spill situations.

7.1 Recommended Exposure Limits

The exposure standards for xylenes (mixtures of the ortho, meta and para isomeric forms) are based upon irritant properties and effects on the central nervous system. Canadian provincial guidelines are generally similar to those of the USA-ACGIH, unless indicated otherwise.

Guideline (Time)	Origin	Recommended Level	Reference
Time-weighted Averages (TWA)			
TLV® (8 h) (ortho, meta, and para isomers)	USA-ACGIH	100 ppm (435 mg/m^3) (skin)	TLV 1983
PEL (8 h) (mixture)	USA-OSHA	100 ppm (435 mg/m^3)	NIOSH/OSHA 1981
PEL (10 h/d, 40 h/wk) (mixture)	USA-NIOSH	100 ppm (435 mg/m^3)	NIOSH/OSHA 1981
Short-term Exposure Limits (STEL)			
STEL (15 min) (ortho, meta, and para isomers)	USA-ACGIH	150 ppm (655 mg/m^3) (skin)	TLV 1983
Ceiling Limit (10 min)	USA-NIOSH	200 ppm (870 mg/m^3)	NIOSH/OSHA 1981
Other Human Toxicities			
IDLH	USA-NIOSH	10 000 ppm	NIOSH Guide 1978
TC_{LO}		200 ppm	RTECS 1979
LC_{LO} (6 h)		10 000 ppm	RTECS 1979

Inhalation Toxicity Index

The Inhalation Toxicity Index (ITI) is a measure of the potential of a substance to cause injury by inhalation. It is calculated as follows:

ITI = 1315.12 (Vapour Pressure, in mm Hg/TLV®, in ppm)

At 30°C, ITI = 1315.12 (9.75 mm Hg/10 ppm)

At 30°C, ITI = 1.3×10^2

7.2 Irritation Data

7.2.1 Skin Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
Unspecified	The liquid is a skin irritant and causes erythema, dryness, and defatting; prolonged exposure may cause the formation of vesicles	NIOSH/OSHA 1981
Unspecified	Percutaneous absorption is generally too slow to produce systemic poisoning although it can result in a characteristic dermatitis	TDB (on-line) 1981
Unspecified	May cause skin to blister. Hemorrhagic inflammatory lesions of mucous membranes leading to acute chemical pneumonitis	TDB (on-line) 1981
SPECIES: Rabbit		
100 percent	Moderate irritation	RTECS 1979
50 mg (24 h)	Moderate irritation	RTECS 1979

7.2.2 Eye Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
460 ppm	Eye irritation to most subjects	Miller 1976
200 ppm	Irritating to the eye	RTECS 1979
Unspecified	There have been reports of reversible corneal vacuolation in exposed workers	NIOSH/OSHA 1981
110 ppm	Initiation of eye irritation in a small percentage of subjects	Miller 1976

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rabbit		
87 mg/m^3	Mild irritation	RTECS 1979
5 mg/m^3 (24 h)	Severe irritation	RTECS 1979

7.3 Threshold Perception Properties

7.3.1 Odour. Odour characteristic: Like benzene, sweet (AAR 1981).

Parameter	Media	Concentration	Reference
Odour Threshold	In air	1.4 ppm	Miller 1976
100 Percent Detection Level		14 ppm	Miller 1976
Upper Recognition Threshold	In air	4.13 ppm	Kirk-Othmer 1984
Median Recognition Threshold	In air	2.21 ppm	Kirk-Othmer 1984
Lower Recognition Threshold	In air	0.26 ppm	Kirk-Othmer 1984
Identification Threshold	In air	40 ppm	Patty 1981
Minimum Detection Threshold	In air	0.17 ppm (ortho) 0.3 ppm (meta) 0.6 ppm (para)	Verschueren 1984

7.4 Toxicity Studies

7.4.1 Inhalation.

Exposure Level (and Duration)	Effects	Reference
Acute Exposures		
SPECIES: Human		
10 000 ppm (18.5 h)	Three workers were exposed. One died from pulmonary edema shortly after exposure. Autopsy revealed petechial hemorrhages in brain. Two workers recovered in 2 days but both had temporary hepatic impairment and one had evidence of temporary renal impairment	Morley et al. 1970. IN NIOSH 1975
1000 ppm (1 h)	Toxic effects	AAR 1981
100 to 690 ppm (15 min)	Six individuals between 21 and 60 years of age were exposed to various concentrations. At 690 ppm, 4 out of 6 experienced dizziness and eye irritation, 2 reported throat irritation and tearing, and 3 stated that they tasted "something". All effects were gone within 1 hour following exposure. At 460 ppm, 4 subjects again reported eye irritation, 1 complained of throat irritation, 1 of tearing and eye irritation. During exposure to 110 ppm, the only symptom reported was mild throat irritation by one volunteer	NRC 1981
100 to 300 ppm (70 min)	Fifteen men, beginning with 30 minutes of exercise on a bicycle in one experiment, and no exercise in the second experiment. Xylene did not cause a notice-	NRC 1981

Exposure Level (and Duration)	Effects	Reference
	able change in subject performance in the latter test. Physical exercise resulted in an increase in uptake of xylene and significant performance decrements were observed in tests of numerical ability, short-term memory and choice reaction time	
>200 ppm	Anorexia, nausea, vomiting, and abdominal pain. Briefer exposures caused irritation of the eyes, nose and throat	NIOSH/OSHA 1981
200 ppm (3 to 5 min)	Irritation of the eyes, nose and throat	Doc. TLV 1981
200 ppm	TC_{LO}	AAR 1981
100 to 200 ppm (3 or 7 h)	No significant changes in tests made of blood pressure, pulse rate, critical flicker fusion rate or reaction time	NRC 1981
0.05 to 0.07 ppm	Four subjects exposed. At 0.07 ppm level, xylene reportedly produced a large change in brain electrical activity, whereas 0.05 ppm had no effect	NRC 1981
Unspecified	The same exposure that produces symptoms in normal people can induce convulsions in those suffering from 'latent' epilepsy	TDB (on-line) 1981
Unspecified	Sensitivity to alcohol is increased by exposure to xylene	TDB (on-line) 1981
0.30 mg/m^3 (para) (2.84 $mmole/m^3$) (4 h)	Four subjects were exposed and their reaction time and memory tested; no effects were noted	Olson 1983

Exposure Level (and Duration)	Effects	Reference
SPECIES: Dog		
4 mg/L (4 h)	Experienced increased lacrimation that began after 1 hour and persisted through the 4 hour exposure period	NRC 1981
SPECIES: Cat		
9500 ppm (2 h) (41 mg/L)	LC_{100}, typical central nervous system effects	Patty 1981
41 mg/L (2 h)	Four male cats died, exhibiting a classic nervous system effect: the sequential development of salivation, ataxia, tonic and clonic spasms and anesthesia followed by death	NRC 1981
SPECIES: Rat		
19 650 ppm (12 h)	Para isomer. Fatalities occurred	NRC 1981
8000 ppm (meta) (4 h)	LC_{LO}	DPIMR 1981
6700 ppm (4 h)	LC_{30}	Patty 1981
6350 ppm (4 h)	LC_{50}	Patty 1981
6125 ppm (12 h)	LC_{LO}	AAR 1981
4912 ppm (24 to 28 h)	LC_{LO}. No deaths occurred when exposed only to para isomer	NRC 1981
2000 to 3000 ppm (24 h)	Fatalities	NRC 1981
2970 ppm (4 h)	Signs of irritation and prostration within 2 to 3 hours	NRC 1981
1340 ppm (2 h)	Poor coordination	NRC 1981
SPECIES: Mouse		
6000 ppm	Lethal concentration	DPIMR 1981

Exposure Level (and Duration)	Effects	Reference
5267 ppm (6 h) m-xylene	LC_{50}	NRC 1981
4600 ppm	Lethal dose	Patty 1981
3907 ppm (6 h)	LC_{50}	NRC 1981
2010 ppm (24 h) (meta)	LC_{LO}	DPIMR 1981
Chronic Exposures		
SPECIES: Human		
350 ppm (2 mo)	One worker exposed to 75 percent xylene containing paint fumes suffered acute episodes of dizziness, incoordination, nausea and loss of appetite	NRC 1981
100 to 200 ppm (6 h/d, 3 d/wk)	The concentrations were produced under two circumstances: in one case levels were maintained at a constant 100 or 200 ppm level and in the second case a TWA level of 100 or 200 ppm was maintained but the actual levels were systematically varied to achieve peak concentrations of 400 ppm. Slight impairment of equilibrium and significant increases in reaction time were noted even at 100 ppm during the first week. These effects were not stable, but reappeared again during the second week of exposure. There were no significant changes in measurements of manual dexterity, flicker fusion, or extraocular muscle balance. Light exercise appeared to counteract the effect of xylene. Xylene values of 30 μ M/L in the blood corresponded to subjects' disturbances in equilibrium (a level which is found in subjects	NRC 1981

Exposure Level (and Duration)	Effects	Reference
	exposed to xylene vapour of 200 ppm or less)	
150 ppm (5 d)	Six subjects exposed. No long-term or serious effects noted	Hake 1981
Unspecified	Signs and symptoms of chronic exposures resemble those of acute exposures. Inhalation of vapours may cause CNS excitation, then depression characterized by paresthesia, tremors, apprehension, impaired memory, weakness, nervous irritation, vertigo, headache, anorexia, nausea and flatulence. May lead to anemia and mucosal hemorrhage. Clinically, no bone marrow aplasia but hyperplasia, moderate liver enlargement, necrosis and nephrosis may occur	Patty 1981
Unspecified	Among workers in a printing office where xylene was predominant in several materials, radiography revealed abnormalities in size and form of the heart in 50 percent of the cases	TDB (on-line) 1981

7.4.2 Ingestion.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
Unspecified	Causes a burning sensation in the mouth and stomach, nausea, vomiting and salivation. Substernal pain, cough and hoarseness, headache, giddiness, vertigo, ataxia, tinnitus, confusion, stupefaction and coma	TDB (on-line) 1981

Exposure Level (and Duration)	Effects	Reference
"Small amount" liquid paint thinner, 90 percent xylene and toluene	Day after ingestion, dextrose and urobilinogen in urine. Toxic hepatitis but total recovery within 20 days	Ghislandi and Fabjani 1957. IN NIOSH 1975
SPECIES: Rat		
5000 mg/kg (*o*-, *m*- or *p*-)	LD_{50}	Miller 1976; DPIMR 1981
4.3 g/kg (4300 mg/kg) (mixed xylenes)	LD_{50}	Patty 1981; Miller 1976
2.5 mL/kg	Lethal to 7 of 10 animals (ortho isomer) Lethal to 3 to 10 animals (meta isomer) Lethal to 6 of 10 animals (para isomer)	Patty 1981

7.4.3 Intraperitoneal.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rat		
2000 mg/kg (mixed, meta or para)	LD_{50}	Miller 1976
1500 mg/kg (ortho)	LD_{50}	Miller 1976

7.4.4 Subcutaneous.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rat		
2500 mg/kg (ortho)	LD_{50}	Miller 1976
5000 mg/kg (meta, para)	LD_{50}	Miller 1976

7.4.5 Mutagenicity, Teratogenicity and Carcinogenicity.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
Unspecified	Study of cohort of 15 cases of lymphocytic leukemia and 30 industry controls revealed that those having contact with solvents are 4.5 times as likely to have lymphocytic leukemia	Arp 1983
SPECIES: Rat		
0.441, 0.147 or 0.004 mL/kg	No significant increases in chromosome aberrations in rat bone marrow cells	NRC 1981
1000 mg/m^3, (24 h/d, d 1 to 21 of pregnancy)	Teratogenicity not proven; however, increased skeletal anomalies were reported such as extra ribs and fused sternebrae	NRC 1981
0.044 to 0.441 mL/kg	No genetic effects observed in bone marrow cell chromosome	API 1978
100 and 400 ppm (6 h/d, d 6 to 15 of pregnancy)	No evidence of fetal sex variation, embryo toxicity, inhibition of fetal growth or teratogenic potential	API MED 1978
SPECIES: Chicken		
Unspecified	Causes developmental defects in chicken embryos	TDB (on-line) 1981
SPECIES: *Saccharomyces cerevisia, Salmonella typhimurium*		
Unspecified	Not mutagenic in a series of short-term tests. Mitotic gene conversion in yeast *Saccharomyces cerevisiae* and gene mutation tests in *Salmonella typhimurium*	NRC 1981
Unspecified	No genetic effects on in-vitro tests, with or without rat liver activator.	API 1978

7.5 Symptoms of Exposure

General symptoms of exposure found in most information sources have not been specifically referenced. Only those of a more specific or unusual nature have their sources indicated.

7.5.1 Inhalation.

1. Irritation of nose and throat.
2. Nervousness.
3. Salivation (Patty 1981).
4. Weakness.
5. Flushing and reddening of the face (Patty 1981).
6. Dizziness.
7. Drowsiness.
8. Nausea.
9. Vomiting.
10. Abdominal pain.
11. Paresthesia.
12. Tremors.
13. Disturbed vision.
14. Staggering gait.
15. Anorexia (NIOSH/OSHA 1981).
16. Impaired memory.
17. Central nervous system depression (Patty 1981).
18. Hepatic impairment.
19. Pulmonary edema (GE 1980).
20. Narcosis (GE 1980).
21. Cardiac stress (Patty 1981).
22. Coma.
23. Death (NIOSH/OSHA 1981).

7.5.2 Ingestion.

1. Burning sensation in mouth and stomach (TDB on-line) 1981).
2. Nausea.
3. Headache.
4. Cramps

5. Vomiting.
6. Gastrointestinal distress (TDB (on-line) 1981).
7. Kidney damage (AAR 1981).
8. Liver damage (AAR 1981).
9. Coma.
10. Death (AAR 1981).

7.5.3 Skin Contact.

1. Irritation.
2. Dryness.
3. Defatting of skin (AAR 1981).
4. Erythema (NIOSH/OSHA 1981).
5. Dermatitis (AAR 1981).
6. Formation of vesicles with prolonged exposure (NIOSH/OSHA 1981).

7.5.4 Eye Contact.

1. Irritation.
2. Irritation of conjunctiva (Lefèvre 1980).
3. Reversible corneal vacuolation (NIOSH/OSHA 1981).

8 CHEMICAL COMPATIBILITY

8.1 Compatibility of *o*-, *m*- and p-Xylenes with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
GENERAL														
Fire		•	•										Flammable liquid vapours form explosive mixtures in air	Sax 1979; NFPA 1978
Heat		•	•										Flammable liquid, vapours may form explosive mixtures when heated in air	Sax 1979; NFPA 1978
SPECIFIC CHEMICALS														
Dichlorohydrantoin (1,3-Dichloro-5,5-dimethyl-2,4-imidazolidindione)		•								•			Upon mixing	Bretherick 1979

8.2 Compatibility of p-Xylenes with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
SPECIFIC CHEMICALS														
Acetic Acid			•										Oxidation of p-xylene with acetic acid can cause an explosion	Bretherick 1979
Nitric Acid			•							•			Violent explosion in closed vessel	Bretherick 1979
CHEMICAL GROUPS														
Oxidizing Agents	•													Dow MSDS 1979

9 COUNTERMEASURES

9.1 Recommended Handling Procedures

The following procedures have been derived from a literature review. To avoid any deviation from the intended meaning, the wording of the original source has been essentially unchanged - in so doing, it is recognized that there may be some discrepancies between different sources of information. It is recognized that countermeasures are dependent on the situation, and thus what may appear to be conflicting information may in fact be correct for different situations. These procedures should not be considered as Environment Canada's recommendations.

9.1.1 Fire Concerns. Xylene is a flammable liquid which gives off flammable vapours at or near normal temperatures. Vapours form explosive mixtures with air and may travel along surfaces to ignition sources and flash back (NFPA 1978). Containers may explode in heat of fire (ERG 1980).

9.1.2 Fire Extinguishing Agents. Water may be ineffective because of scattering or spreading of the xylenes (DPIMR 1981). Use water spray to cool containers involved in a fire to prevent rupture (GE 1980; NFPA 1978).

Small fires: Dry chemical, CO_2, water spray or foam.
Large fires: Water spray, fog or foam.

Move containers from fire area if this can be done without risk. Stay away from tank ends. For massive fires, use unmanned hose holder or monitor nozzles (ERG 1980).

9.1.3 Spill Actions.

9.1.3.1 General. Stop or reduce discharge of material if this can be done without risk. Eliminate all sources of ignition. Avoid skin contact or inhalation (GE 1980). A fluorocarbon water foam can be applied to the spill to diminish vapour and fire hazard (EPA 670/2-75-042).

The following absorbent materials have shown possible applicability for vapour suppression and/or containment of xylenes: cellosize and hycar (ICI 1982). Materials recommended for plugging leaks of *o*-xylene are polyester (glad bag), imid polyester (brown-in-bag) (EPA 600/2-76-300) and sea-going epoxy putty (EPA 68-01-0106).

9.1.3.2 Spills on land. Contain if possible by forming mechanical or chemical barriers to prevent spreading, and recover as much liquid as possible. Adsorb remaining spilled

material with sand or vermiculite and shovel into covered metal containers for disposal (GE 1980; EPA 670/2-75-042). Other recommended sorbent materials are polyurethane foam and most oil spill sorbents (CG-D-38-76).

9.1.3.3 Spills in water. Contain if possible with booms or natural barriers to limit spreading. Remove trapped material with suction hoses or oil skimming equipment (EPA 670/2-75-042).

9.1.4 Cleanup and Treatment.

9.1.4.1 Spills on land. If the spilled material has been contained in a holding area, vacuum equipment and/or sorbents can be used to remove the slick (OHM-TADS 1981).

9.1.4.2 Spills in water. After containment of spilled material with booms, (oil) skimming equipment and/or sorbents can be used to remove the slick (OHM-TADS 1981). If solubilized in water, apply activated carbon at 10 percent the spill amount over the region occupied by 10 mg/L or greater concentrations. Use mechanical dredges or lifts to remove the activated carbon and pollutants for disposal (EPA 670/2-75-042).

9.1.4.3 General. For treatment of contaminated water, gravity separation of solids followed by skimming of the surface to remove spilled material is recommended. If skimming is not sufficient, dual media filtration followed by carbon adsorption should be considered. The recommended carbon ratio is 1.0 kg to 3.5 kg soluble material. The wastewater from backwash of the filtration and adsorption units is returned to the gravity separator (EPA 600/2-77-227).

The following treatment processes have shown possible applicability for spill countermeasures:

Process	Percent Removal (TSA 1980)	Process	Maximum Percent Removal (EPA-600/8-80-042E)
Biological	92 to 95	Solvent Extraction	>97
		Carbon Adsorption	68 to 99

9.1.5 Disposal. Recovered xylene must never be discharged directly into sewers or surface waters. The material may be burned in an approved incinerator or disposed via a licensed solvent disposal company (GE 1980).

9.1.6 Charcoal Filtration Data (EPA 600/8-80-023). The following recommended values for the removal of p-xylene in water by either the single stage powdered carbon contactor or the granular carbon column adsorption system were obtained using the Freundlich Adsorption equation. The derivation of the equation is discussed in the Introduction Manual.

SINGLE STAGE POWDERED CARBON CONTACTOR SYSTEM

Initial Concentration (mg/L)	Carbon Doses (mg/L)	Final Concentration (mg/L)
1.0	15	0.1
1.0	24	0.01
0.1	2.2	0.01

GRANULAR CARBON COLUMN SYSTEM (ESTIMATED)

Initial Concentration (mg/L)	Carbon Doses or Requirements to Achieve Breakthrough (mg/L)
1.0	12
0.1	1.9
0.01	0.3

9.1.7 Protective Measures. For entry into a situation where the spilled material and its characteristics are unknown, self-contained breathing apparatus and a totally encapsulated chemical suit should be worn.

If the spill material is known to be xylene:

- Response personnel should be provided with and required to use impervious clothing, gloves, face shields (20 cm minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid or solid xylene (NIOSH/OSHA 1981).
- Splash-proof safety goggles where liquid or solid xylene may contact the eyes are also recommended (NIOSH/OSHA 1981).
- Polyvinyl alcohol showed a breakthrough time of greater than 1 hour. Nitrile, polyurethane and Viton showed a breakthrough time of approximately 1 hour. Butyl

rubber, natural rubber, neoprene and PVC showed a breakthrough time of less than 1 hour (Little 1983).

- Any clothing which becomes wet with liquid xylene should be removed immediately; nonimpervious clothing which becomes contaminated with xylene should be removed promptly and not reworn until the xylene is removed from the clothing (NIOSH/OSHA 1981).
- Buna-N rubber gloves and aprons are recommended (GE 1980).
- Eye wash stations and safety showers should be readily available in areas of use and spill situations (GE 1980).

The following is a list of the minimum respiratory protection recommended for personnel working in areas where xylene is present (NIOSH/OSHA 1981).

Condition	Minimum Respiratory Protection* Required above 100 ppm
Vapour Concentration	
1000 ppm or less	A chemical cartridge respirator with a full facepiece and an organic vapour cartridge(s).
5000 ppm or less	A gas mask with a chin-style or a front- or back-mounted organic vapour canister.
	Any supplied-air respirator with a full facepiece, helmet, or hood.
	Any self-contained breathing apparatus with a full facepiece.
10 000 ppm or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 10 000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
	A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.

Condition (Cont'd)	Minimum Respiratory Protection* Required above 100 ppm
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapours.
	Any escape self-contained breathing apparatus.

* Only NIOSH-approved or MSHA-approved equipment should be used.

9.1.8 Storage Precautions. Store in closed containers in a clean, cool, well-ventilated area away from sources of heat, sources of ignition, and strong oxidizing agents. Protect containers from physical damage. Bond and ground metal containers when transfering liquid. Use metal safety cans for small amounts. Use nonsparking tools for work in solvent areas. No smoking in areas of use, storage, or manufacturing (GE 1980).

9.2 Specialized Countermeasures Equipment, Materials or Systems

The following items are taken from a previous study (Dillon 1982) and should not be considered to be the only suitable specialized countermeasures equipment, materials or systems available. More details on the specifications, performance and availability of these items can be found in the referenced study.

Recovery from Water - Floating Materials	Amine Carbamate Gelling Agent and Application System
	Oil Mop
Temporary Storage	Portable Collection Bag System
Removal from Water	EPA Mobile Physical/Chemical Treatment Trailers
Treating Agents	Hazorb (Sorbent)

10 PREVIOUS SPILL EXPERIENCE

10.1 General

This section contains information on previous spill experience which will be useful to readers in understanding spill responses and countermeasures. Only those which meet the criteria are included, and thus, the number of experiences is not an indication of the problems or frequency of spillage. As technology in spill control advances, this section will be updated in future manual revisions to include the most useful information.

10.2 Train Derailment (PC EES 1982; HMIR 1981)

In a train derailment in a rural area, one of five derailed tank cars ruptured and spilled approximately 98 500 L of xylene. Response crews immediately constructed two earthen dykes to contain the spilled product in a drainage ditch adjacent to the railroad. Most of the contained xylene evaporated before cleanup crews arrived 2 days later. The remaining product was then pumped out of the ditch and disposed of. The cleanup crews wore protective clothing and respirators to prevent contact and inhalation of xylene. As well as the xylene, 20 to 30 m^3 of contaminated soil were removed from the spill site. Since there was still concern for groundwater contamination, water samples were taken at nearby wells. The analysis results revealed no detectable concentration of xylene in the water.

11 ANALYTICAL METHODS

The general approach adopted for each of the Priority Chemicals was as follows.

Methods have been documented here for the analysis of samples from air, water and soil in a normally equipped chemical laboratory remote from the spill site. Customary sources of standard or recommended analytical methods were consulted, and outlines are presented for each chemical. These sources included publications of the U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. Environmental Protection Agency (EPA), the American Water Works Association (AWWA), the American Society for Testing and Materials (ASTM), and the American National Standards Institute (ANSI).

If the standard or recommended methods were judged to be reliable and specific enough for the analysis of environmental and materials samples from spill sites and if they do not require highly specialized laboratory equipment, no additional methods were sought.

If especially simple, reliable tests (e.g., commonly used industrial methods) were found, they have been presented as well.

11.1 Quantitative Method for the Detection of Xylene in Air

11.1.1 Gas Chromatography (NIOSH 1977). A range of 210 to 870 mg/m^3 (50 to 200 ppm) of xylene in air may be determined by gas chromatography using flame ionization detection. A known volume of air is drawn through a 7 cm x 6 mm O.D. charcoal tube containing two sections of 20/40 mesh activated charcoal separated by a 2 mm portion of urethane foam. The first section contains 100 mg whereas the second section contains 50 mg. A silylated glass wool plug is placed before the front absorbing section. A sample size of 12 L is recommended at a flow rate of 200 mL/min.

The charcoal tube sample is scored before the first section of charcoal and broken. The larger section of charcoal is transferred to a 2 mL stoppered sample container containing 1.0 mL of carbon disulphide. The same operation is performed with the back-up section. The samples should be allowed to desorb for 30 minutes. A 5 µL aliquot of sample is injected into a gas chromatograph equipped with a flame ionization detector. Typical gas chromatograph conditions are: nitrogen carrier gas flow at 50 mL/min, hydrogen gas flow at 65 mL/min, air flow at 500 mL/min, injector temperature at 215°C, column temperature of 180°C, and a detector temperature of

275°C. The column is 3 ft. long, 1/8 in. O.D., stainless steel, packed with porapak Q. The xylene is determined using an electronic integrator to measure the area under the peak in conjunction with a standard curve.

11.2 Qualitative Method for the Detection of Xylene in Air

The sample is collected as in Section 11.1.1 and desorbed. A suitable portion of sample is treated with hot potassium permanganate. The formation of a precipitate indicates the presence of a xylene. This is not specific for xylene. If more positive identification is needed, the acid derivative of xylene is isolated and its melting point determined (348°C) (Morrison 1976).

11.3 Quantitative Method for the Detection of Xylene in Water

11.3.1 Partition Infrared (AWWA 1981). A range of 40 to 400 ppm (40 to 400 µg/mL) of xylene in water may be determined by partition infrared spectrophotometry. A minimum of 1 L of a representative sample is collected in an appropriate container. The sample is acidified to pH 2 with approximately 5 mL of 50 percent hydrochloric acid. The sample is transferred to a separatory funnel and the container rinsed with 30 mL of Freon® 113 (1,1,2-trichloro-1,2,2-trifluoroethane) and the washings added to the separatory funnel. The solvent layer is filtered into a 100 mL volumetric flask. Two more 30 mL extractions are done and the extracts combined with the first in the 100 mL volumetric flask. The volume is adjusted to 100 mL with solvent. The xylene is determined using matched 1 cm near-infrared silica cells and a suitable double-beam I.R. recording spectrophotometer. The sample is scanned from 3200 cm^{-1} to 2700 cm^{-1} with Freon® in the reference beam. A standard curve is used to determine the quantity of xylene in the sample.

11.4 Qualitative Method for the Detection of Xylene in Water

The sample is collected as in Section 11.3.1 but not acidified. A suitable portion of sample is treated with hot potassium permanganate. The formation of a precipitate indicates the presence of a xylene. This is not specific for xylene. If more positive identification is needed, the acid derivative of xylene is isolated and its melting point determined (348°C) (Morrison 1976).

11.5 Quantitive Method for the Detection of Xylene in Soil

11.5.1 Gravimetric (AWWA 1981). This method may be used for the detection of concentrations greater than 40 ppm xylene in soil. Approximately 20 g of soil, accurately

weighed, are collected in a glass jar and dried by the addition of magnesium sulphate. Freon® 113 (1,1,2-trichloro-1,2,2-trifluoroethane) is used to extract the xylene. It is distilled from the extraction flask on a water bath. A temperature of 70°C must be carefully controlled or sample loss will be a problem. Air is drawn through the flask for the final minute. The flask is then cooled and weighed. This is a simple, inexpensive method.

11.6 Qualitative Method for the Detection of Xylene in Soil

A suitable soil sample is placed in an extraction flask and extracted with Freon® 113 (1,1,2-trichloro-1,2,2-trifluoroethane) and the Freon® reduced in volume by evaporation. A suitable portion of sample is treated with hot potassium permanganate. The formation of a precipitate indicates the presence of xylene. This is not specific for xylene. If more positive identification is needed, the acid derivative of xylene is isolated and its melting point determined (348°C) (Morrison 1976).

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EnviroTIPS

Common Abbreviations

BOD	biological oxygen demand
b.p.	boiling point
CC	closed cup
cm	centimetre
CMD	count median diameter
COD	chemical oxygen demand
conc	concentration
c.t.	critical temperature
eV	electron volt
g	gram
ha	hectare
Hg	mercury
IDLH	immediately dangerous to life and health
Imp. gal.	imperial gallon
in.	inch
J	joule
kg	kilogram
kJ	kilojoule
km	kilometre
kPa	kilopascal
kt	kilotonne
L	litre
lb.	pound
LC_{50}	lethal concentration fifty
LC_{LO}	lethal concentration low
LD_{50}	lethal dose fifty
LD_{LO}	lethal dose low
LEL	lower explosive limit
LFL	lower flammability limit
m	metre
m	meta
M	molar
MAC	maximum acceptable concentration
max	maximum
mg	milligram
MIC	maximum immission concentration
min	minute or minimum
mm	millimetre
µg	microgram
µm	micrometre
°Be	degrees Baumé (density)
MMAD	mass median aerodynamic diameter
MMD	mass median diameter
m.p.	melting point
MW	molecular weight
N	newton
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
nm	nanometre
o	ortho
OC	open cup
p	para
P_C	critical pressure
PEL	permissible exposure level
pH	measure of acidity/alkalinity
ppb	parts per billion
ppm	parts per million
P_S	standard pressure
psi	pounds per square inch
s	second
STEL	short-term exposure limit
STIL	short-term inhalation limit
T_C	critical temperature
TC_{LO}	toxic concentration low
Td	decomposition temperature
TD_{LO}	toxic dose low
TL_m	median tolerance limit
TLV	Threshold Limit Value
Ts	standard temperature
TWA	time weighted average
UEL	upper explosive limit
UFL	upper flammability limit
VMD	volume mean diameter
v/v	volume per volume
w/w	weight per weight